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JOURNAL OF THE
NATIONAL ASSOCIATION OF DOCUMENT EXAMINERS
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Editorial

Some time during a document examination career, it is likely that an examiner will be approached to examine handwriting written in a language unfamiliar to the examiner. The examiner must decide whether to accept the assignment, and if the assignment is undertaken, then the examiner must seek out the necessary background information in order to complete the examination. Dr. Marianne Nürnberger has written an extensive, illustrated case study covering Arabic handwritten signatures, Arabic print, and an Arabic stamp. The article contains excellent information about a writing system very different from that learned by most document examiners, and it clarifies the necessity of anyone undertaking an examination in a "foreign" script to have the input of a native writer to avoid potential misunderstandings regarding the characteristics of the written language.

Another difficult area of handwriting examination is the correct assessment of tremor in handwriting. Tremor can be a sign of a simulation or tracing process, but it can also be related to various internal or external factors. Heidi H. Harralson has written an article entitled Handwriting Characterization and Differential Analysis of Parkinson's Disease and Essential Tremor, accompanied by a glossary and an annotated bibliography on this topic. Ms. Harralson is working on a Masters of Handwriting Science degree at Prescott University. This individual study program is very challenging and intensive. The article presented here is typical of the work required regularly. One focus of the program is to bring together information on handwriting found in other fields, such as medicine and motor control.

An article by your chief editor on Calibration of Optical Reticules was inspired by a presentation on this topic at a recent workshop on Microscopy at the College of Microscopy outside Chicago, Illinois. Most microscopes have an eyepiece with a built in reticule, and for those that do not, it is usually possible to purchase an add-on reticule or a different eyepiece/reticule combination. The reticule should be calibrated at each magnification level in each microscope where it will be used. This article explains the calibration process and explains how any NADE member can borrow the equipment required for the calibration process from the NADE Library.

Staple Holes are a key factor in solving a case in the Case Notes article by Kay Micklitz. The issue is rounded out with information on Laser Printers in the Forensically Speaking section, and the Authorities Speak Out section on the topic of "Tracing." It is the editorial board's fondest hope that these articles will inform the reader, and perhaps stimulate the reader to write an article for a future issue of this journal.

On a personal note, this will be the last issue presided over by the current Chief Editor. Editing this journal has been a privilege and a pleasure, but also a time-consuming adventure. It is time to give someone else the opportunity to continue and improve this important resource. Thank you to the co-editors, contributors and readers who have made this experience so worthwhile.

Emily J. Will, Editor

Case study: Six feigned Arabic signatures, one prototype in Arabic print and an Arabic stamp

by
Doz.Dr. Marianne Nuernberger

The examination of handwriting in a foreign language is a particular challenge for a handwriting expert. Six signatures of an Arabic name were examined in the course of a court case: signatures X1 and X2 on a bill of exchange, X3 on a deed of gift, on a proxy (X4) for the Austrian suspect N., also two signatures found on the documents of an Austrian association (X5 and X6). Since all of them were in one way or the other provided by the same suspect N., none of them could be classified as "known." Even the Austrian association to which the documents with the signatures X5 and X6 were attributed, had been founded by the suspect N. and his son.

X1, X2 and X3 are placed like abstract signatures above a blue stamp with Arabic writing. X4, X5 and X6 consist, in each case, of the written name plus an abstract signature below, which partly looks like an underline. See illustration 1.

The sources of the relevant particularities of Arabic writing presented in this case are reports written by the Austrian Arabist and linguist, Mag. Roswitha Irran from Pinkafeld, and by the Austrian university lector for Arabic and sworn-in interpreter for Arabic and English, Mag. Christine Schlager from Graz, respectively. The Austrian university lector for Arabic and Arabic native speaker Mag. Abdullah Bersenji from Graz finally looked through the manuscript.

Related facts

The bill of exchange in question was for a very large sum (9,560,000 USD). In the course of the lengthy examinations concerning the authenticity of the documents, an accused Austrian, N., made extensive statements concerning the person who had made the Arabic signatures in question. According to him, it was a very rich, very successful Arabic speaking and writing Moslem businessman from Dubai of advanced age who dealt, amongst other things, in precious gems.

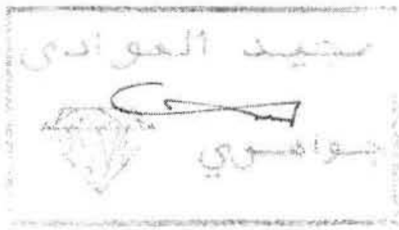
Extensive international police investigations at home and abroad were unable to find any evidence for the existence of the person allegedly responsible for the signatures being analysed here.

A paper was found where N. lived which showed, in Arabic toner print and in Latin capital letters, the name in question, *Majid Al Awadi* (see illustration 2). Additionally, there were printed transcriptions in Latin letters under the signatures X4, X5 and X6 (see illustration 1). The same basic Arabic forms of the name are to be found on the stamp of the abstract signatures in question, X1, X2, X3, and in the legible parts of the signatures X4, X5, and X6. See illustration 2.

The signatures X4, X5 and X6, which are richer in examinable criteria, show more similarities between the signatures X5 and X6 than these two signatures to X4, although all three were dated the same. This is also the case for the abstract signature-like shapes below the legible part of the three signatures. There are three plausible hypothetical explanations for this:

The Arabic signatures in question and the stamp

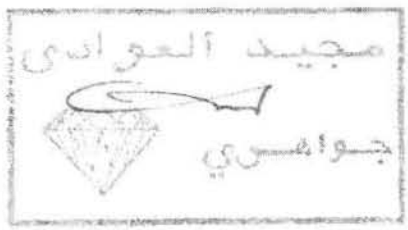
Illustration 1



from original, original size

from original, enlarged, ca. 200%

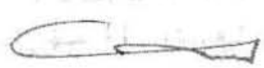
X1 (abstract signature above company stamp), dated 29.11.1995



from original, original size

from original, enlarged, ca. 200%

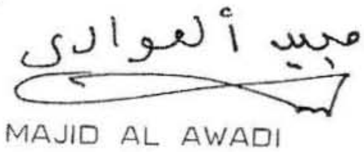
X2 (abstract signature above company stamp), dated 30.10.1998



from original, original size

from original, enlarged, ca. 200%

X3 (abstract signature above company stamp) dated 30.10.1998



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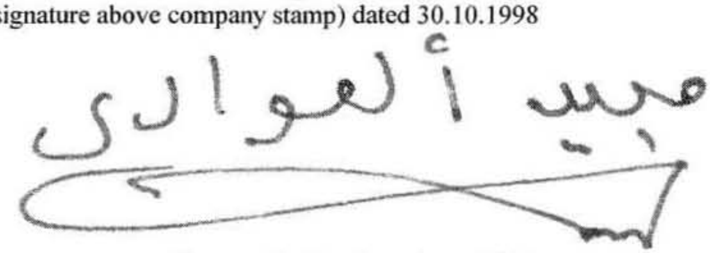
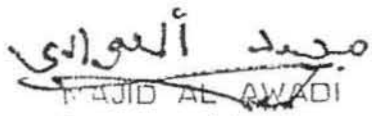


from original, enlarged, ca. 200%

X4 (writing direction: from left to right), dated 07.03.1996



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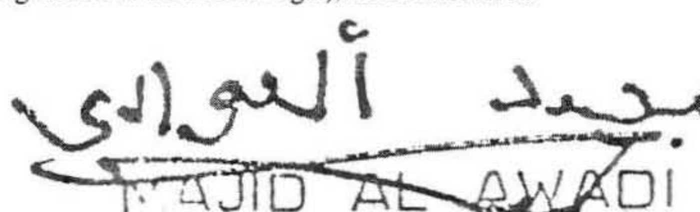


from copy, enlarged, ca. 200%

X5, dated 07.03.1996

from copy, original size

from copy, enlarged, ca. 200%

X6, dated 07.03.1996

Illustration 2

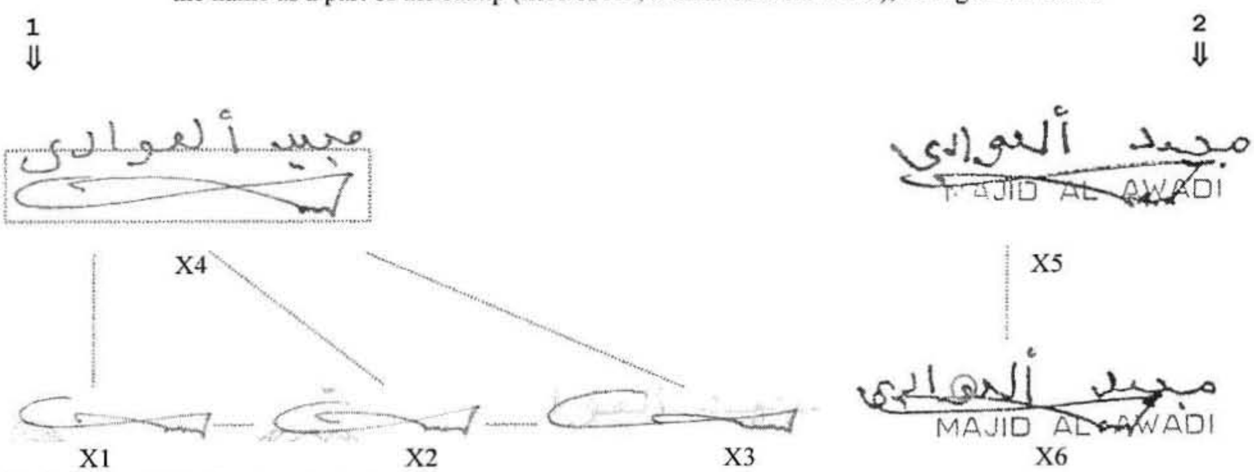
Diagram: Relations between prototype and imitations, groups of similarities

مجيد ألعوادى

printed prototype: name in Arabic toner print

مجيد ألعوادى

the name as a part of the stamp (here of X2, similar of X1 and X3), enlarged ca. 200%



Similarities divide the signatures in two groups:

1- more rounded shapes and more even stroke in X4,
similarity of dimensions in the abstract part of the signature of X4, the isolated abstract signatures X1, X2, and X3.

2- more overall angularity, more obvious holding points, more uneven breadth of stroke in the written name-parts of X5 and X6,
similarity of dimensions in the abstract signatures of X5 and X6.

1- The signature X4 was wrongly dated. X4 shows less differentiation between letters, less precision of form and more fluency of movement. Hereby the thesis of backdating for a longer time span presents itself. "Precision of form," "differentiation of letters" and "lack of affluence," all three as a group of signs, hint towards a writer, who is a beginner, someone just learning to write. When precision and differentiation

decline while affluence is developing, the writer could have already had more practice by the time he made X4[1]. The degree of difference between X4 and both X5 and X6 is, in my opinion, so extreme that a time lapse of at least some days would have to be an additional factor if the results were from one and the same hand.

2- The signature X4 originated from another hand than the signatures X5 and X6.

3- One must also always consider as a possible cause for the noticeable variance in a series of signatures, the feigned character of the series as a whole. Fake signatures, as has been seen, tend to vary more greatly than genuine signatures due to the lack of the process of automation, when the writing of the forger is substantially different.

A similar remarkable difference can be found between the abstract signatures X1, X2 and X3, and the abstract signature part of X4 on the one hand and the abstract signatures under X5 and X6 on the other. The latter are wider and more closely placed under the legible name part, were more clearly not made in one stroke, and have different proportions and angles. The abstract signatures X1, X2 and X3 and the abstract signature part of X4 belong to one group of similarities, whereas the abstract signatures under X5 and X6 belong to a second group of similarities. Similar hypotheses as above may accordingly be applied here:

1- The abstract signature parts and abstract signatures are wrongly dated. To be more precise, the abstract signature parts of X5 and X6 were made either decisively before or decisively after X1, X2, X3, and the abstract part of X4. The readable part of X4 suggests, in the way described above, that this part was done after the readable parts of the signatures X5 and X6. Whereas the analysis of the abstract part of X4 does not give a similar clue to its being done prior to or after X5 and X6. This can at least partly be attributed to the fact that the two above mentioned parameters, "differentiation of letter" and "precision of form," cannot play any part in the analysis of the abstract forms (since no letters or customary form is being followed) and that it cannot be proved that the abstract part of the signature X4 is decisively more fluently done than the other abstract signatures. The only thing that can be said is: Since the abstract part of X4 is nonetheless somewhat different from those of X5 and X6 it was either done at another date or ...

2- The abstract signature part of X4 and the abstract signatures X1, X2, X3 originated from another hand than the signatures X5 and X6.

3- Another possible cause for the noticeable variance in the series of the abstract signatures and abstract signature parts is the feigned character of the series as a whole.

Evidence for the non-Arabian authorship of the Arabic names and abstract signatures in question and of the printed prototype and the stamp

1.- Writing direction

Arabic is written from right to left. It will certainly be of general interest to writing experts that, as was mentioned to the author in business correspondence, certain cases are known in

Spain where signatures of Arabian names were written in the wrong direction, that is, from left to right, in order to hide their true authorship. Mandel (2004:150f) illustrates a completely different kind of exception to the Arabic writing direction. It concerns the domain of the thousand-year-old Arabic artistic calligraphy, where mirror composition (*mutanna*) is used as a style element to obtain the aesthetic effect of symmetry through duplication of a text in mirrored writing.

The signature X4 is the only example in a legible style where the original was available for examination.

My co-worker Julian Horky diagnosed the writing direction of X4: under the stereo microscope the writing procedure could be seen from the deposits of ink on the edges of the strokes at certain crossings. It was seen to have been written from left to right, the wrong direction for Arabic. See illustration 3.

The photograph shown in Illustration 3 was made on the appliance "Docucenter" from the firm Nikon. The luminescence procedure shows here with particular plasticity the results gained from the stereomicroscopy.

Specialist reference to this simple case of Arabic forgery can be found, amongst other sources, in Ellen (1997:37). Thus, it must be considered proven that X4 can by no means have been the usual signature of an aging Arabian businessman.

2.- Writing system

The Arabic letters and signs used in the printed prototypes for the signatures of the name *Majid Al Awadi* were identified through the work of Mandel (2004) and can be seen in illustration 4. Additionally, the stamp of the signatures X1, X2 and X3 shows the word *Jawāhirī*, which, according to Schlager (2005:1) is derived from the Arabic root "Gem" and means something like "the one who has to do with gems." See illustration 5.

The prints, that is the toner print on the fragment of paper and the stamps with the signatures X1, X2, X3 all show, according to Schlager, the Arabic writing form *nashi*, a form of print which is used in most types of print, as in newspapers and books. The "i" (the Arabic letter *Yā*) at the end of the words *Awadi* and *Jawahiri* is differently written. As a rule, when *Yā* is written at the end of a word and without a dot, like here in *Awadi*, it is pronounced "a". Actually, *Yā* is only pronounced "i" when written with two dots below, as here in *Jawahiri*. Schlager (ibid.) says that it can happen that the two dots at the end of the word may be omitted, as is frequently the case with commonly used expressions in newspapers, but for a serious businessman it would be unacceptable to have on the one hand a company stamp with variant writing or, on the other, for him to write his own name with negligence.

The writing form of the Eastern Arabian region is called *ruq^{c}a*[2] and is different in a number of ways from the *nashi* which will later be shown in more detail.

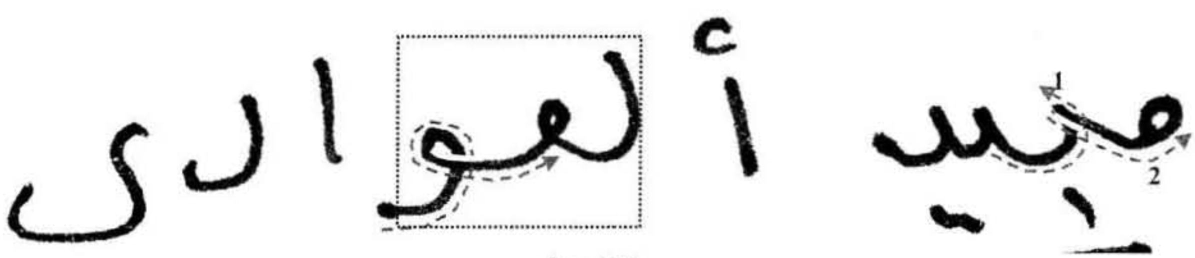
3.- Clumsiness of writing

The printed prototype and the legible parts of the signatures in question are, regarding the style of writing, similar, although Arabic handwriting and print are subject to different rules.

Illustration 3

Simulation of Arabic script in rightward writing movement

enlarged, ca 350%

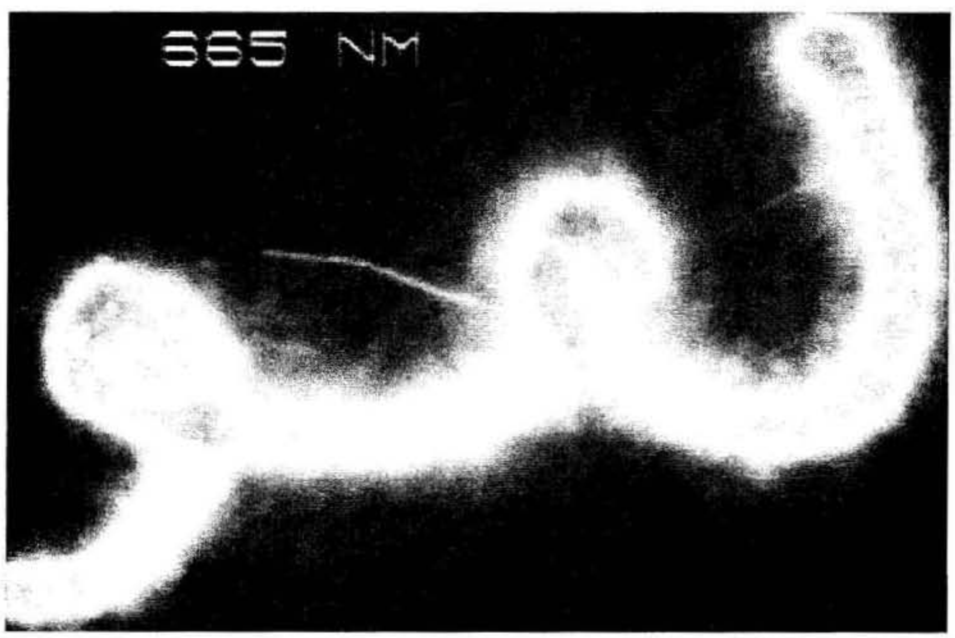


from X4

Arrows: direction of stroke from left to right, as opposed to Arabic writing direction.

Light grey markings: in marked areas the deposits along the stroke are, due to a shining wall of ink, under the stereomicroscope with an enlargement of 48:1 particularly clearly visible.

Dotted rectangle: roughly the section of the photo below.



The appliance for the examination of documents, "Docucenter" (LGK Graz) from the company Nikon, illustrates by filtering with 665nm in luminescence procedure the course of the stroke from left to right, as opposed to the Arabic writing direction.

مجيد ألعوادى			
Mīm ("m"of "Majid")	مـ	*Lām* ("l" in "al") and *'Ayn* (guttural sound) as second "a" of "Awadi"	لـع
Jīm ("j" of "Majid", sound as in "joy")	جـ	*Wāw* ("w" in "Awadi")	و
Yā ("i" of "Majid")	يـ	*Alif* ("a" von "Awadi")	ا
Dāl ("d" of "Majid")	د	*Dāl* ("d" von "Awadi")	د
Hamza above *Alif* ("a" in "al")	أ	*Yā* (end-"i" of "Awadi") two dots for distinguishing from "a" are missing under this letter	ى

Illustration 4

جـواهـــري
the word *jawāhirī* from the stamp to X2
ي
Yā (end-"ī")

Illustration 5 – Enlarged by 200%

Taking into consideration the fact that Arabic writing cannot be individually formed or treated with negligence to the same extent as writing in Europe (Ellen 1997:23), the following signs of weakness in Arabic writing technique may, according to the Arabists Irran (2004), Schlager (2005) and Bersenji occur:

The punctuation[3] under the handwritten letters of the first part of the name *Majid* should be missing in the case of a normal signature, but in a written name without actual signature character, as in this case, it should be exactly placed. In X4, X5 and X6, however, it is on the one hand there and misleadingly placed and on the other hand partly missing. See illustration 6.

In Eastern Arabic handwriting (*ruk^{c}a*), as opposed to print, the two dots above or below a letter are, for the sake of increasing the speed of writing, if at all, only represented by a short stroke. These two dots (that is, the stroke under the *Yā* in *Majid*) display, according to Schlager (2005:2f) in X4 the wrong angle of inclination; they should slant from above right to below left or be horizontal. The wrong angle of inclination here could indicate a wrong writing direction. See Illustration 6, marked by arrow and oval. In X5 and X6 the stroke under the *Yā* seems to be missing and is instead placed under the *Jīm* (see illustration 6, marked by an oval). The dot under the *Jīm* is also shifted to the right, below the *Mīm* (see illustration 6, marked by a circle).

Added to that, one can hardly recognise the *Jīm* in X4 due to the neglected writing style. See Illustration 6.

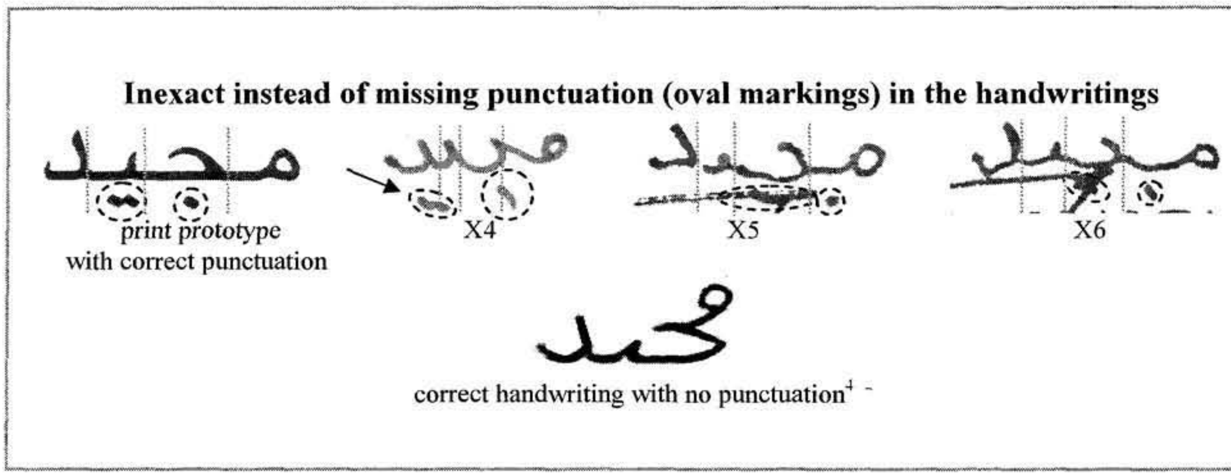


Illustration 6

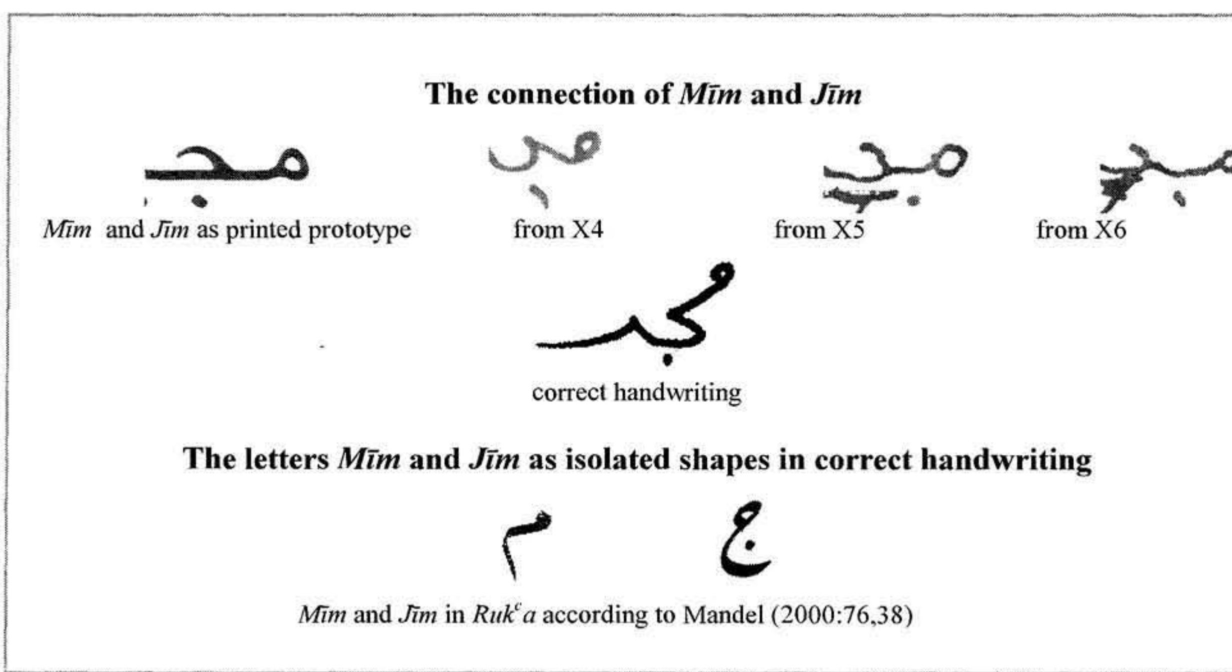


Illustration 7

The form of a single Arabic letter depends on its context (see illustration 7) that is, whether it is at the beginning, in the middle or at the end of a word. Some letters in the middle must be joined up at the beginning and at the end; others may only be joined up in one direction or not at all.

and *Bā*), thus the name "Majid" wrongly as e.g. "Mobayed" or "Mobid." This connection is also incorrect in X5 and X6, a further hint towards an attempt that had obviously been made to copy a print prototype.

Excerpt from an Introduction to Arabic writing from Brustad et al. (2001: 121)

Now write the Arabic name for Egypt,مجيد:

When writing initial مـ followed by ج , ح , or خ , remember to draw the loop well above the line so that you can continue directly into the next letter. Copy the name مجيد :

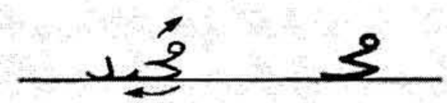


Illustration 8 - computer-graphically enhanced

Arabic writing has strict rules with regard to joining up, not joining up and connecting letters. If these are not followed, Arabic texts become illegible.

The connection between the *Mīm* and the *Jīm* is wrong. Correct versions are shown in illustration 7 and in illustration 8.

In the joining of the *Mīm* and the *Jīm* in the questioned signatures, there is no change of level of alignment, which is characteristic for the beginning of the letter *Jīm*. In such a case, according to Schlager (2005:2f), the letters in question in X4 can be read as "m" and "b" (*Mīm*

To this, Schlager (2005:1f) points out that it is, amongst other things, an essential characteristic of *nashi*, an Arabic printing style, that the letters which have no lower length – that is, in the example shown here, all the letters of the name *Majid* and in *Al Awadi* all letters except *Wāw* and *Yā* – are all written on the same level of alignment. This is contrary to the writing style, which, to increase the speed of writing, makes use of certain simplifications, and to compensate for this, is written on different levels. According to an illustration by *Aloyoni (2003:4)* these levels of alignment are a characteristic feature of both the common handwriting styles, *ruqᶜa and*

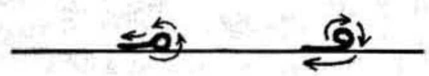
nasksh. They also occur in Arabic calligraphy. In the questioned signatures, however, the *nashi printing* style of writing on the same level is imitated at the beginning of the name *Majid*, which is entirely unusual for common handwriting.

In the two letters "*Mīm* at the beginning of the word" and "following *Jīm*" the *Mīm* would have to be placed higher, as illustrated as correct writing (see illustration 7) and as shown by an excerpt from a course in Arabic[5] (see illustration 8).

The *Mīm* at the beginning of the word is represented by a circle which must be written depending on the next letters to the right or to the left. The turning to the left (if written in correct writing direction!) of the curl-in before a *Jīm* in X5 and X6 is against the rules. See Illustration 9.

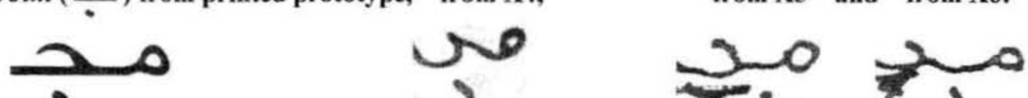
From an Introduction to Arabic writing from Brustad et al. (2001: 121)

There are two common styles of writing initial ـمـ. It may be looped up and over, just like independent م, or looped from underneath, in the opposite direction. Once you have closed the loop, continue on into a connecting segment. Copy and practice both examples, then choose one form to use:



Correct form of *Mīm* and *Jīm* according to Brustad et al. (2001: 121):

***Mīm* (ـمـ) and *Jīm* (ـجـ) from printed prototype, from X4, from X5 and from X6:**



Mīm looped with correct appearance[6] in X4, with wrong appearance in X5 and X6

Illustration 9

Examples of movement of the writing in Arabic

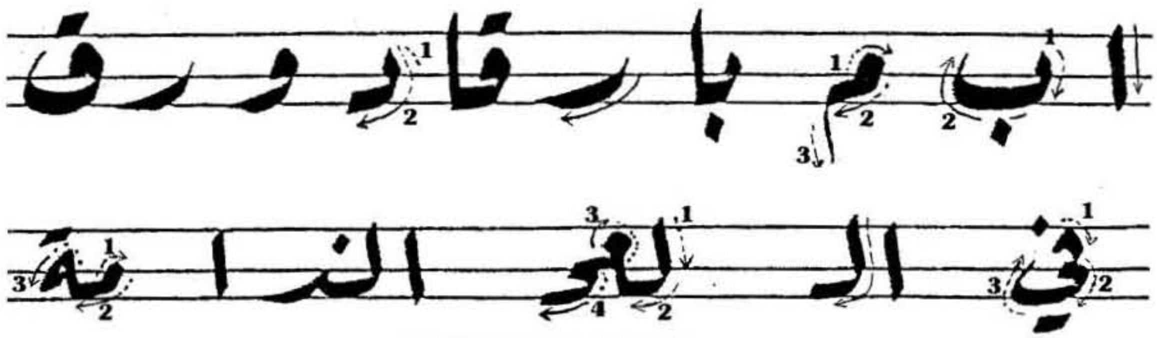


Illustration 10

Formation of two *Dal* in X6

Dashed circles: too different overall shape of the two *Dal*, arrows: incorrect oblique line to (or from) below right

Illustration 11

Wrongly written instead of missing *Hamza* above *Alif* in the connection *Alif* and *Lām* and an unusual soldering at the lower end of *Lām*

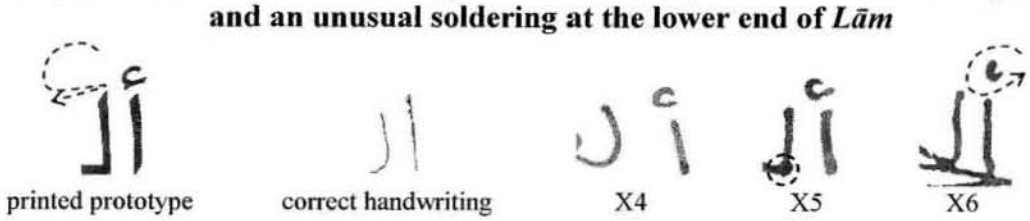


Illustration 12

The consulted Arabists deduce that X5 and X6 could by no means have been made by an adult Arabian person, since it is only in first stages of learning to write Arabic that anticlockwise movements may be used in a *Mīm* circle, when connected to a *Jīm*. This is even more so since the natural personal development process of writing Arabic can have hardly any effect on the rules of connection or writing direction, since the slightest degree of variation can cause loss of legibility. Some more examples of the prescribed movement of handwriting in Arabic are shown in illustration 10.

Some of the questioned letters at the left end of a word such as the *Dal* at the end of the word *Majid* in X6 and the *Ya* (pronounced "i") at the end of the name *Al Awadi* in X5 and X6, have, differently from X4, a small oblique stroke to (or from, depending of the direction of writing) the right, which is wrong. This superfluous line, according to Schlager (2005:3) and Bersenji, could only have been made by a beginner with little writing practice. To my opinion this may point to the use of a prototype in imitating a quill-pen-like appearance of thick endings (or beginnings, depending on the direction of writing). According to Bersenji, both the letters *Dal* in X6 are, apart from that, too different from each other to have been made by an adult Arabian. See illustration 11.

The *Hamza* above the *Alif* is wrongly written; the horizontal closing line to the left is missing. Apart from that, it is not usual in handwriting to place a *Hamza* above an *Alif* in the word *Al* which is being used as an article, unless the word is at the beginning of a sentence. See illustration 12.

In X5 the writing was broken off after the *Lām*, which would be very unusual for an Arabic native speaker. See illustration 12, marked by circle.

The *ᶜAyn* is not distinctive enough, that is, particularly in X4 it is too similar to a *Mīm* or a *Fā'*. See illustration 13.

- The *Wāw* in X5 was incorrectly added on and runs unusually; the connecting stroke runs above instead of below the loop. See illustration 14.

- The baseline alignment of the legible parts of the signatures in question is not correct. As opposed to European writing, great importance is attached to the baseline alignment in Arabic, and much trouble is taken with it in the process of learning to write. It is an important, difficult to master, and strictly-to-be-followed peculiarity of Arabic handwriting.

4.- Types of Arabic signatures

According to Aloyoni (2003:5f) there are three main forms of Arabic signatures. Legible signatures (*almaguru*) of the whole name, as in the forms of X4, X5 and X6, are very rare in Arabian countries (Aloyoni ibid:3, Irran 2004:1). In most *Almaguru* signatures, only parts of the name are legible.

The commonest form of Arabic signature is a one-piece mixture of written and abstract signature, (Irran: ibid., Aloyoni 2003:6), called *fermah* (Aloyoni ibid.) which as a rule, however, as opposed to the questioned signatures X4, X5

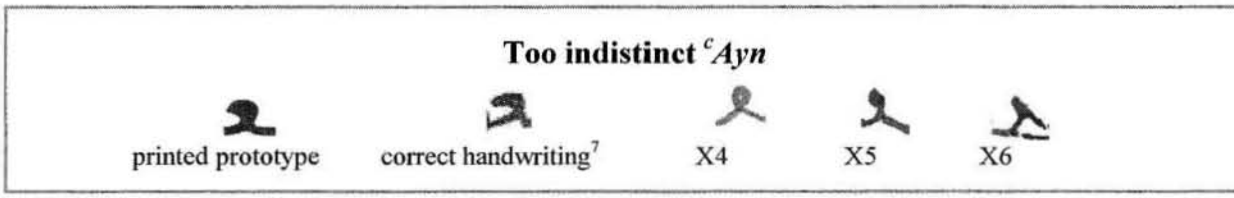


Illustration 13

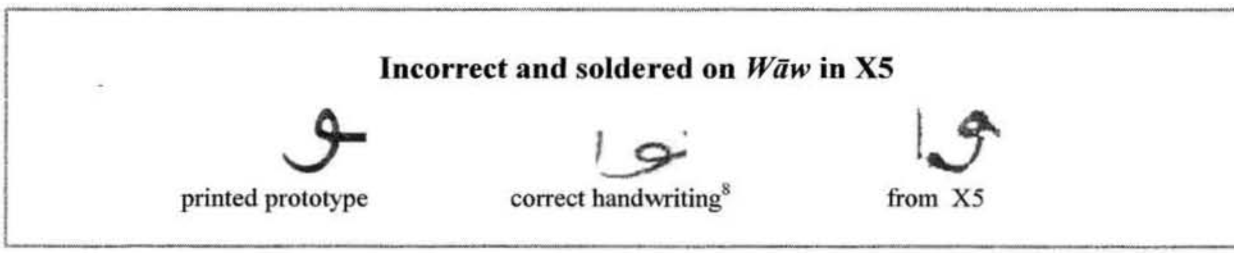


Illustration 14

Illustration 15

and X6, only contains part of the name, plus an abstract signature joined to the legible part.

Illegible abstract signatures (*gharmagru*), a kind of symbol for the person signing, are also common (Aloyoni 2003:5).

Illustration 15 shows three examples of genuine Arabic signatures[9] from the hand of an Arabian called Majid Alawadi.[10]

5.- Character of stroke, movement in the writing, form[11]

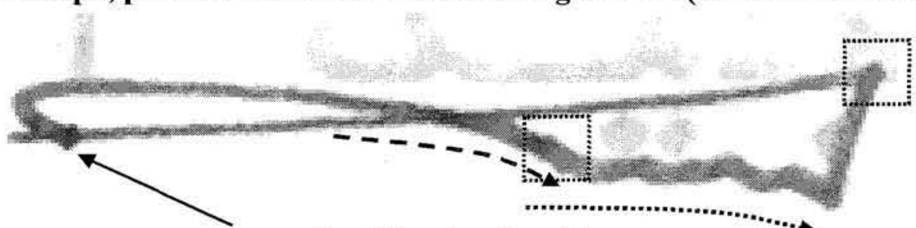
The abstract signatures in question are not only left unattached to the legible name-parts, they also show no signs in themselves of Arabic origin. The character of the strokes indicates that the abstract signatures start at the left with a long, flat curve, to which some very small, slowly and clumsily-made irregular teeth are attached, followed by a vertical line, which slightly turns to the right and ends in a large garland which drops abruptly down toward the left from the top of the vertical line. There is no sign of any kind of letter whether of Arabic or other origin in it. The absence of letter forms is not unusual for Arabic abstract signatures.

What is unusual is the obvious lack of flow in any of the more differentiated parts of the abstract signatures. The partly slow and uneven way the strokes were made in the originals X1 to X4 and, particularly in X5 and X6 even in the copies visible, obvious adding on at the corners, indicate forgery or fake. Much room is given in specialist literature to such general warning hints of forgery (e.g. Michel 1982: 124, 139, 145, Pfanne 1954:92, Nickel 1996:48-50). The application of more specific research (Lieblich et al. 1975, Shannon 1978) on leftward-trend writing systems shows that the rightward-trend of the fairly differentiated parts of the abstract signatures indicates an author who is more familiar with our writing system or some writing system related to ours than with the Arabic system. Only the extended end-stroke could eventually be the result of a leftward movement of the pen. End-strokes are strokes of a somewhat less important or (better termed) secondary type, in the sense that they do not constitute letters or meaning and they play a more decorative part in a signature. Their direction very often does not conform with the general writing direction. Therefore, the sole direction of the simple end stroke cannot be judged significant for a cultural classification of the forgery.

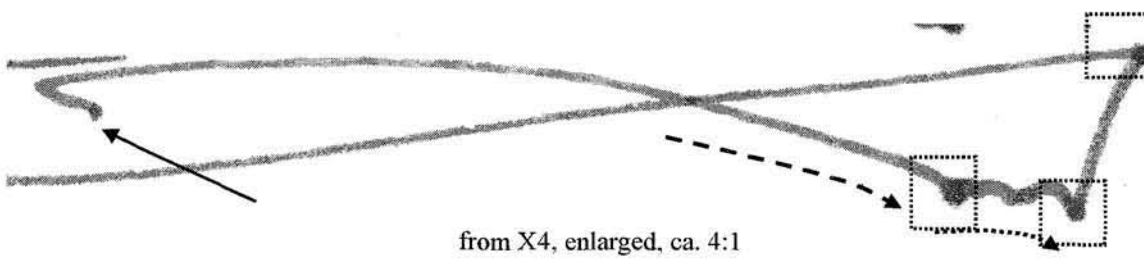
The abstract signatures and names X1, X2, X3, X4, all four examined from the original, all give the typical clumsy, uncertain and in significant parts lifeless general impression of badly made forgeries. Many recognised writing experts have drawn attention to the importance of lifelessness (e.g. Pfanne 1954:92, Michel 1982:139), the lack of automation and spontaneity (Seibt 1999:63), the contradiction between flow of movement and character of stroke (Hoffmann 1989:333) such as an overall simple form executed in slow movement as warning signs of forgery. The intervals, pauses and soldering of lines of the abstract signatures visible under the stereomicroscope, as also the obvious slow, uneven, exactly added-on and carefully drawn lines in parts of all the questioned writings

which result in the blunt conclusion of the lines and which are also visible in the copies of X5 and X6, speak the same language (see illustration 16).

Change of tempo, point of hesitation and soldering of lines (results from the original)



from X3, enlarged ca. 1:6



from X4, enlarged, ca. 4:1

Continuous arrow: point of hesitation or uncertainty at the beginning of the line and slow beginning of the line
dotted rectangle: soldering,
dashed arrow: doughy and slowing down stroke toward the right,
dotted arrow: doughy, very slow stroke along the wavy part of the line.

Illustration 16

Furthermore, the following signs found in the questioned abstract signatures, which speak against a normal automatic writing process, are described in methodical accordance with the recommendations of specialist literature (e.g. Michel 1892:124, 139, 145, Pfanne 1954:92, Nickel 1996:48-50, Seibt 1999…etc.):

- the arrhythmic change of tempo of the stroke in the very slow passages wherever the slightest steps of differentiation are made, that is at the beginning and the end, where a change of direction takes place and in the wavy line also
- widening of the strokes[12], indicating a lack of flow, on some line endings and on many places showing change of direction or other differentiations,
- the soldering always being in different places,
- the unmotivated and the slow line endings,
- the contradiction between the painted-looking, repeatedly hesitant lines and the simple overall appearance.

The low degree of personal imprint in the written parts of the signatures in question, X4, X5 and X6, the lack of homogeneity which can also be seen in the copies of X5 and X6 and the extremely uneven baseline alignment of the legible parts of the signatures contribute to the impression that they are not written by an Arabian adult man whose natural writing is Arabic.

Many signs of forgery are to be found particularly in X5 and X6[13]: lack of spontaneity, massive widening of the strokes, which can indicate change of tempo and pressure[14], wrong connections, breaks in the continuity of the strokes, shakiness, heterogeneity of the irregularities, static appearance of movement in the writing,...etc. Additionally, the small circle of the letter *Mīm* in X5 and X6 is written in the opposite direction to the one in X4. This is a further indication that X4 was made at a different time to X5 and X6, or was written by another person. This phenomenon is not to be expected in genuine signatures, because of the process of automation.

The result of the examination

From the arguments shown above, it can be seen that all six signatures shown here, ostensibly made by a rich Arabian businessman from Dubai, are feigned, and that the abstract signatures as well as the legible parts of the signatures were not made by an adult Arabic native speaker.

It is possible that in spite of the variation between the specimens, all signatures were made by the same person.

The stamp of the Signatures X1 to X3 also has variant and unusual writing styles, which a serious Arabian businessman would not tolerate. The absence of punctuation below the last letter in the name on the toner print and the stamp both point to a non-Arabian origin of the stamp, or at least to the low orthographical and cultural standard of the author[15].

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Name and Address of the authoress: Marianne Nürnberger (Univ.-Doz. Dr.)A-8554 Soboth 58

The authoress is a certified sworn-in expert in the examination of handwriting and is an inaugurated member of the Institute for Social and Cultural Anthropology of the University of Vienna.

[1] This thesis presupposes that both the other signatures, as also X4, were written from left to right, which is, from the copies, neither provable nor refutable.

[2] According to Aloyoni (2003:4) there are two styles of handwriting which are in common day to day use in Arabian countries, ruqca and naskh. According to Irran (2004) and Schlager (2005), the only commonly used handwriting in the Eastern Arabian region is ruqca.

[3] According to Aloyoni (2003:2), the way the diacritics (additional signs) are used in Arabic is highly valuable in the identification of the authorship of forgeries.

[4] According to Brustad et al. 2001:121

[5] A copy of the explanations of Brustad et al. (2001) was provided by Schlager.

[6] The loop of the *Mīm* in X4 only appears to be written correctly. Remember that the whole signature is (as shown above) written from left to right!

[7] This example is taken from the sample of the signature of Mister Majid Alawadi, which he kindly made available for this article. Mister Majid Alawadi has nothing whatsoever to do with the signatures being treated in this case study. He kindly agreed to help me with it, because of the similarity of the name.

[8] See footnote 7

[9] They represent the three forms of signature used by Mister Majid Alawadi in the last eight years.

[10] Although the name *Majid Alawadi* is practically consonant with the name *Majid Al Awadi* of the signatures being examined here, there are more differences here in the Arabic way of writing than one might suppose from the Latin transcription.

[11] Thanks to Dr. Angelica Seibt for her criticism of some formulations in this section.

[12] The parts in the original of the material in question, X1 to X4 all show flat, hardly noticeable signs of pressure. Light dents in single corners of the abstract signatures in question are evidence of pauses. The widening of the strokes in X1 to X4 is, therefore, hardly evidence of increased pressure, far more of slowing down of the movement of the writing!

[13] Some of the evidence mentioned, particularly the breaks in the continuity of the strokes and the shaky lines are not able to be diagnosed without doubt from the copies, as they could have been simulated by mistakes in the copying.

[14] See foot note 12.

[15] Bersenji concludes by stating that in Arabian countries company stamps which show neither an address nor any other possibility of establishing contact, as in this case, are absolutely not customary. Apart from that, it is hardly conceivable that an Arabian native speaker would sign a bill of exchange of such great value with only the abstract signatures X1 and X2 and not with a fully written name.

Handwriting Characterization and Differential Analysis of Parkinson's Disease and Essential Tremor

by
Heidi H. Harralson

Abstract
Parkinson's disease (PD) and essential tremor (ET) are movement disorders that frequently impair handwriting. A review of medical research on PD and ET can assist forensic document examiners in characterizing the handwriting of common health-related handwriting disorders. Medical treatments for movement disorders and the way they affect handwriting are also reviewed. A comparison of PD and ET handwriting, based on a review of medical research, indicates they have characteristics that can allow for differential analysis: PD can manifest resting tremor, rigidity, slowness, micrographia, changes in direction, and/or variance in size, speed, and baseline; ET manifests a handwriting action tremor with a higher frequency than PD tremor. Medical clinicians and researchers use subjective rating scales to quantify tremor in handwriting. Research has shown correlations between objective measurements and ratings from subjective ordinal scales. In handwriting identification methods and research, forensic document examiners can adapt clinical rating scales to quantify dynamic information from static handwriting samples.

Handwriting identification issues concerning motor disorders frequently appear in probate cases involving the disputed signatures of elderly or deceased persons. Forgery also occurs in cases where elderly persons have been exploited financially. As the elderly are prone to motor disorders such as Parkinson's disease and are an at-risk population for financial abuse, it is not infrequent that forensic document examiners investigate cases involving signatures of the elderly. From a social perspective, the elderly population is increasing and financial exploitation of said population is one of the most prevalent forms of elder abuse (Schiamberg & Gans, 2000). As a result, forensic document examiners can expect to see an increase in cases involving movement disorders.

Because movement disorders can seriously impede handwriting fluency, at times the handwriting or signature has little or no resemblance to the original handwriting pattern exhibited by the writer prior to onset of the movement disorder. Even if a handwriting pattern can be established after the onset of the disorder, some patients exhibit a variation that can change daily; and, some patients use medical treatments that can temporarily (and partially) improve handwriting fluency. The problem is further complicated by the variety to which differing motor disorders can influence the patient's handwriting. The knowledge offered by motor control research can be used by document examiners to characterize and possibly differentiate the handwriting of motor disorders such as Parkinson's disease and essential tremor. Additionally, through qualitative observations and the use of subjective clinical scales reported in medical research, document examiners could develop more reliable methods in differentiating motor disorders from simulation.

Extensive medical research exists on the diagnosis, assessment, and treatment of movement disorders. Because handwriting is a habitual, fine motor skill, analysis of changes or fluctuations in a patient's handwriting is frequently employed as an assessment aid. Clinicians and researchers use a variety of tools to assess fine motor dysfunction in handwriting including subjective, visual inspection scales and objective measurement devices such as accelerometers and digitizing tablets. These tools aid in establishing how movement disorders manifest as handwriting disorders.

In handwriting identification cases, movement disorders can present significant problems. Although it is well established in handwriting identification theory that no two writings are exactly alike, identification is grounded on a pattern-based principle (Conway, 1978; Harrison, 1958; Hilton, 1993; Huber & Headrick, 1999; Osborn, 1929). Theoretically, identification is possible because an individual writing under normal conditions will consistently produce similar patterns within certain parameters or range of variation. There are extraordinary internal and external factors that can potentially affect handwriting and its natural range of variation. Internal factors, such as motor disorders, have a significant influence on handwriting to the extent that they can dramatically alter the writer's established pattern and natural range of variation. Gathering a collection of handwriting comparison standards that accurately reflects the writer's range of handwriting habits is critical in cases involving handwriting disorders. However, the number of contemporaneous handwriting exemplars available in movement disorder cases is frequently insufficient. As a preemptive measure, document examiners could inform the public about fraud prevention strategies to protect the elderly by documenting progressive deterioration or treatment through periodic witnessed affidavits or reaffirmation of wills. Although a periodic record of the signature would be ideal, currently, the comparison standards available in most cases involving motor disorders do not provide a complete record of the writer's full range of writing habits.

Motor Disorder Characterization and Effects of Treatment

There are a number of motor disorders and each disorder has a variety of characteristics dependent on the severity of the condition and the unique way it manifests in the patient. Additionally, two or more motor disorders can coexist. For comparison purposes, two of the most common disorders, Parkinson's disease and essential tremor, are discussed. The cause of the movement disorder is addressed as well as how it affects the motor control system and handwriting specifically. Finally, treatments for each disorder and how various treatments influence or change handwriting are reviewed.

Parkinson's Disease

Parkinson's disease (PD) is diagnosed as a progressive, degenerative motor system condition related to basal ganglia dysfunction. Phillips, Stelmach, & Teasdale (1991) state that PD "is a disease of older age, associated with the loss of dopaminergic cells in the substantia nigra that project to the striatum…this loss causes disturbances of basal ganglia function and results in disturbances of motor control" (p. 302). Teulings, Contreras-Vidal, Stelmach, & Adler (2002) further describe the disorder as "deficits in learning new movement patterns, and deficits in proprioceptive and kinaesthetic feedback…in particular, in handwriting movements, patients with Parkinson's disease exhibit more variable peak accelerations and sizes/stroke, and smaller than normal handwriting—that is micrographia" (p. 315). Boisseau (as cited in Teulings, Contreras-Vidal, Stelmach, & Adler, 1997) "observed that PD handwriting can be characterized by various types of dysfluencies: lack of control, abrupt changes in direction, tremor, slowness, hesitation, rigidity, variability of baseline, and in some cases, micrographia" (p. 159). See Figure 1.

The primary symptoms associated with PD are tremor, rigidity, and bradykinesia/akinesia (slowness of movement) (Hristova & Koller, 2000; Pal, Samii, & Calne, 2002; Phillips et al., 1991; Teulings et al., 2002). According to Hristova & Koller (2000), two of these three symptoms are necessary for diagnosis of PD, however, it was noted by Duncan & Wilson (as cited in Pal et al., 2002) that "almost all elderly people…attending a day care and nearly one-half of the neurologically 'normal' elderly people seen in a community had at least one feature…of parkinsonism" (p. 41). The three primary symptoms of PD can directly influence the fine motor control necessary to execute fluent handwriting movements. Tremor creates a tremulous line quality; rigidity causes jerks and angularity in handwriting forms; and bradykinesia decreases handwriting speed and can result in micrographia (small handwriting) and uncoordinated handwriting movements. Phillips et al. (1991) state that "some patients report the difficulty making their signature on cheques one of the more stressful aspects of their disease" (p. 302).

Tremor. Tremor is the most widely noticed first symptom of PD and one that is characteristically present in handwriting as the disease progresses. In the early stages of the disease, tremor may be present only at rest. As soon as writing starts the tremor disappears. It is reported by Bain (2002) that most Parkinson's patients show signs of asymmetrical (one side of the body) tremor with approximately 60% exhibiting postural tremor (p. 4). Pal et al. (2002) note that "approximately 70% of patients notice tremor as the first symptom" and it is characterized as having a 3-5 Hz (frequency) with rhythmic "pill-rolling" movements and varying amplitude (p. 43). Symptoms typically start on one side of the body and with progression of the disease, both sides are affected. Additionally, the dominant hand (or side of the body) is typically the side affected with more severity (Uitti, Baba, Whaley, Wszolek, & Putzke, 2005).

Rigidity. Rigidity is also a common symptom of PD. According to Pal et al. (2002), rigidity in PD is asymmetrical, present in the wrists, and is characterized as "an increased resistance to passive movement." It was further noted that "bradykinesia and rigidity usually occur together" (p. 44). Dietz (as cited in Joseph, 1996) discussed how PD patients not only demonstrate rigidity and akinesia, but also "freezing of movement" (p. 337). In characterizing handwriting, this resistance or frozen movement could cause angular or awkward movements where circular movements are typically found in rounded letter formations. See Figure 2. Hesitation might also occur in areas of the handwriting where fast, spontaneous movement is expected.

Bradykinesia. Weakness in the muscles is associated with Parkinson's disease and it is theorized by Berardelli, Rothwell, Thompson, & Hallett (2001) that muscle weakness results in bradykinesia. Bradykinesia is slowness of movement, and as the disease advances the movement becomes even slower. Pal et al. (2002) claim that "bradykinesia is the most disabling component" of PD and that "bradykinesia and rigidity usually occur together and in most cases are comparable in severity" (p. 44).

Micrographia. Other features that can characterize PD include micrographia and variance in the control of movement size and speed. See Figure 3. Not only do instances of

micrographia appear in about 10-15% of PD cases, but patients typically "are unable to sustain normal-sized writing for more than a few letters" (McLennan as cited in Phillips et al., 1991, p. 302). Van Gemmert, Adler, & Stelmach (2003) indicate that "control of movement amplitude and speed may be the source of two distinctive symptoms often observed in such patients, namely hypometric and bradykinetic movements" (p. 1502). The authors further note that movements of increased complexity are problematic for PD patients and can be seen in corresponding complex handwriting movements. They state: "If it is assumed that an alternating letter pattern—for example, *i*'s (sharp reversals) and *l*'s (curved reversals)—is more complex than a letter pattern of *l*'s only, patients with PD should be more affected than age-matched controls by the alternating letter pattern, which requires the subject to make alternations between sharp and curved reversals" (p. 1502-3). Van Gemmert et al. found that PD patients had a harder time writing the more complex movements when required to increase size and speed. Similar results were found by Longstaff et al. (2003) in a study of PD patients with micrographia and age-matched controls. The PD patients demonstrated more movement variability when increasing size and speed in a spiral writing task. It was hypothesized that PD patients choose to write smaller in order to control movement variability.

Some researchers have shown that PD patients exhibiting micrographia can consciously alter their handwriting. It was found that external cues increased the size and speed of the handwriting or drawing in PD patients (Longstaff et al., 2003; Oliveira, Gurd, Nixon, Marshall, & Passingham, 1997; Van Gemmert, Teulings, Contreras-Vidal, & Stelmach, 1999). This suggests that if PD patients direct their attention to the handwriting task, changes in the size and speed of the handwriting can be made. Further, writing guidelines enable the patient to write at normal sizes as suggested by the guidelines.

Medical treatments. PD has known pharmacological and surgical treatments which can improve handwriting fluency and other symptoms. Levodopa or L-dopa is the most frequently used drug therapy to treat symptoms of Parkinson's disease, and its use does have an effect on handwriting. According to Hristova & Koller (2000), levodopa is the most effective treatment, but it does not totally eliminate all symptoms: "Intravenous levodopa infusions have been shown to decrease substantially, but not eliminate, motor fluctuations...10 days of continuous intravenous levodopa infusion gradually decreased the variance of motor fluctuations with each successive day of treatment" (p. 170). Klawans (1986) demonstrated that levodopa prevented further progressive deterioration and sometimes even improved the handwriting of PD patients over a period of 10 years. The Poluha, Teulings, & Brookshire (1998) study showed that when patients take their medication, they start slow and stiff with tremor and small, slow movements. When the medication takes effect, the patient has less tremor and larger, faster movements.

Other pharmacological treatments are administered for PD, but with less effectiveness in both the symptoms of PD as well as in handwriting fluency. Dopamine agonists (DAs),

though less potent than levodopa, are used to treat PD (Hristova & Koller, 2000). "DA delays the time to the appearance of and decreases the incidence and severity of levodopa-induced motor complications and dyskinesias" (p. 170). However, DAs can have adverse effects in causing dyskinesia in as many as 60% of cases of patients with early PD (p. 172). Anticholinergic drugs (ACh) tend to "improve rigidity and tremor by 10 to 25%" (p. 171). COMT inhibitors are used in conjunction with levodopa "when motor fluctuations appear" (p. 171). NMDA receptor blockers are used for reducing dyskinesias (p. 172). Neurosurgical procedures are typically used only in advanced cases of PD. Pallidal stimulation "has a particular effect on reducing dyskinesias and dystonias" (p. 172). A recent pilot study (Shulman et al., 2002) showed that alternative remedies such as acupuncture treatment may improve tremor and handwriting in PD patients.

According to the literature, pharmacological treatments have a significant effect on improving handwriting performance, but probably not to the degree that the handwriting will return to its original fluency (i.e., prior to onset of the disease). Further, the dosage, type of drug, and patient's response are all contributing factors to the effectiveness of the drug treatment. Possible side effects, as well as varied response to the disease, could also impact handwriting fluency. For example, Pal et al. (2002) note that the presence of tremor in the early years of PD can be sporadic, but handwriting can be used in early diagnosis as micrographia can appear in some patients up to 10 years prior to onset.

Essential Tremor

Tremor is the primary clinical feature of essential tremor (ET). Unlike PD which tends to have a resting, asymmetrical tremor (occurring on one side of the body), ET manifests as an action, symmetrical tremor (occurring on both sides of the body). ET mainly affects the upper extremities, such as the head and the hands, but it especially affects the hands causing a kinetic tremor (Biary & Koller, 1987). Interestingly, even though Pal et al. (2002) claim that ET "is the most common movement disorder" (p. 46), there is some uncertainty as to its cause. According to Biary & Koller, "the pathophysiology of essential tremor is unknown" but CNS dysfunction may be a cause (p. 473). A case study on tremor in a single family helped to show how it can be genetically inherited (Cohen, Hallett, & Sudarsky, 1987) while in a 200-patient study, Martinelli, Gabellini, Gulli, & Lugaresi (1987) found that "a family history of tremor was reported by 40% of the patients" (p. 107). In characterizing its progress over time, Elble, Brilliant, Leffler, & Higgins (1996) state that ET "begins insidiously and is initially very mild" (p. 73). In a case reported by Kachi, Rothwell, Cowan, & Marsden (1985), a patient's tremor occurred during the start of the writing task and disappeared during the remaining period of the writing task (p. 547).

ET is sometimes referred to as benign essential tremor because it is the only presenting symptom and is regarded as not having a significant negative impact on the patient. Some clinical researchers (Koller, Biary, & Cone, 1986) contend that the condition is not so benign. Many patients are socially embarrassed by the tremor that can occur in the hands and in the shaking of the head. While interviewing patients, Koller et al. found that "writing a signature was a common problem, particularly in public, and most patients had discontinued all activities that involved writing" (p. 1002). See

Figure 4. The embarrassment experienced by patients with tremulous handwriting causes problems in handwriting identification, as the strength of the opinion is frequently dependent on the quantity of handwriting specimens available that characterize the motor condition of the writer over time.

Tremor is the predominant symptom of ET and is the characteristic that directly affects the motor system and handwriting in particular. The handwriting tremor of ET frequently manifests as a kinetic action tremor which occurs "during any form of movement" (Bain et al., 1993, p. 869). Bain (2002) classifies ET as a symmetrical tremor (p. 5). Pal et al. (2002) characterize ET as a "tremor of faster [higher] frequency (6-9 Hz)" (p. 46), while the Biary & Koller (1987) study found the mean frequency at 4.6 Hz with a range of 3.6 to 6.0 (p. 472). Kachi et al. (1985) report tremor frequency ranging from 5-6 Hz and describe the tremor in their study of 10 patients as "a rhythmic pronation/supination of the forearm, which in eight cases had the 'sinusoidal' character of a true tremor; in the other two cases, the movement appeared more jerky" (p. 547).

There are pharmacological treatments which can affect the symptoms of ET and improve handwriting fluency. Propranolol and primidone are two common pharmacological treatments used for ET and studies have reported that their use has produced an improvement in the handwriting of some patients (Kachi et al., 1985; Koller et al., 1986). Biary & Koller (1987) reported that clonazepam was effective in suppressing kinetic tremor in all of its 14 ET patients tested (p. 473). Some ET patients use alcohol as a remedy for tremor. However, Bain (2002) claims that subsequent to the alcohol use, the tremor later rebounds. Use of alcohol as a way to treat ET can further complicate handwriting identification as alcohol also affects handwriting fluency, but not in the same way as ET. Aside from pharmacological treatments, ET can fluctuate due to stress and day-to-day variance. Additionally, tremor may not appear consistently throughout the handwriting pattern. See Figures 5 and 6.

Differential Analysis

In analyzing and comparing the clinical features associated with PD and ET and the way in which both disorders influence handwriting, some distinctions can be made. However, PD and ET manifest in a variety of forms, and, even clinicians--who frequently have more information about the patient--can have difficulty making diagnoses. PD uniquely shows tremor at rest which may disappear entirely during writing. The tremor in ET remains present during rest and action. Further, there is typically an absence of rigidity, bradykinesia, and micrographia in ET (Hristova & Koller, 2000; Pal et al., 2002) that differentiates it from PD. Changes in direction, variability in size, speed, and baseline, hesitation, and lack of control are characteristics of PD. As PD patients exhibit tremor at rest, they may not have tremor present in their handwriting. However, as the disease progresses, PD patients can develop an action tremor that gradually becomes more severe. Figure 7 is an example of tremor in a PD patient. In ET handwriting, tremor is the primary feature. Generally, ET has a higher tremor frequency than PD, but the tremor in PD may be more consistently present throughout the handwriting pattern. Motor disorders can

coexist and tend to vary. It has been pointed out that not only can PD and ET coexist, but if action or handwriting tremor is present in a PD patient, then there may be an alternative cause for the tremor (Hristova & Koller, 2000; Joseph & Young, 1992).

Clinical researchers have detected dynamic handwriting features that can aid in distinguishing PD from ET. Can these dynamic features be detected from static handwriting samples? According to the Bain et al. (1993) tremor study, "grading spirography and handwriting would appear to be useful because the impairment seen in those tasks correlated well with disability" (p. 872). However, in many handwriting identification cases, acquiring request exemplars demonstrating the effects of the motor disorder is not possible because the writer is either incapacitated (due to the disease), or deceased. Accurate assessment of movement disorders from handwriting is frequently dependent on an adequate number of exemplars demonstrating the writer's day-to-day variation, possible deterioration, and/or medical treatment. This is complicated by patients who, because their handwriting lacks fluency, are not particularly inclined to write unless absolutely necessary. Further, a document examiner's training may limit his or her ability to understand the complexities involved with movement disorders. Bain et al. (1993), in assessing tremor from the static trace using a clinical rating scale, remark that "the scale relies on the examiners having some experience of movement disorders" (p. 868). Blind studies of document examiners, similar to the studies conducted on blind raters in the medical literature, can establish their ability to identify and quantify handwriting dysfluency.

Subjective clinical scales reported in medical literature can be applied to handwriting identification methods. Medical research has shown a correlation between the measurement of handwriting tremor frequency and/or amplitude from accelerometers and digital tablets with subjective measurements of static handwriting and drawing samples. Bain & Findley (1993) developed a subjective scale to measure the severity of tremor from zero to ten and illustrated the scale with examples of tremor for each point on the scale. See Figure 8. Although Elble, Sinha, & Higgins (1990) reported that "precise measures of tremor amplitude and frequency are not possible with...subjective assessments of clarity and smoothness" (p. 193), a subsequent tremor study by Elble et al. (1996) showed how a simple four-point ordinal rating scale was used in comparison with the spectral peak data from digital tablet recordings. The same showed that "the tremor amplitudes (acceleration or displacement) agreed nicely with the ordinal ratings of tremor" (p. 74). Use of a five-point ordinal scale was employed in an ET study by Biary & Koller (1987). In the Koller et al. (1986) study, 18 patients treated with propranolol and primidone were studied and the results showed that handwriting improved with therapy. A blind rater rank ordered the handwriting samples (both treated and untreated) from best to worse and "the worst specimen occurred more frequently in the untreated condition" (p. 1003). In a study on the direction of tremor using spiral drawings, Wang, Bain, Aziz, & Liu (2005) found that the "spiral drawing can be used clinically for quantifying amplitude and frequency of arm tremor" (p. 192). These studies suggest that application of subjective rating scales to handwriting disorders can be a useful and practical way for document examiners to quantify dynamic information from the static trace.

Although motor control research provides useful information that can be used in handwriting identification cases, document examiners need to be cautious with the data provided by this type of research. Clinicians frequently use handwriting as a tool in combination with other diagnostic aids while document examiners rely solely on analysis of the static trace. If a differential analysis is possible, the signs may be subtle and the possibility for coexisting disorders and variation may limit handwriting as a reliable aid in making differential analysis among several movement disorders, especially in ones that have similar handwriting characterization. More important to document examiners, though, is whether the writing can be individualized. In analyzing kinematic and muscular characteristics of self-generated finger movements, Vallbo & Wessberg (in Wing, Haggard, & Flanagan, 1996) found that these movements had individualized speed variations and discontinuities. "Speed variations tend to recur with a rate of 8-10 Hz…the amplitude and the amount of 8-10 Hz varies between subjects but it is relatively constant within the same subject. Hence, the velocity pattern appears to be a kind of fingerprint of the individual subject's control system for finger movements" (p. 369-71). In exploring the causes of movement variability in PD patients, Longstaff et al. (2003) state it could be attributed to "the production and maintenance of muscle forces" and "the coordination of muscle joints" (p. 303).

Medical research offers possible avenues of research in handwriting examination through exploration of motor system individualization and disorder as it is manifested in the static handwriting trace. The research indicates that differential analysis based on qualitative observations of handwriting is possible in some cases. PD can exhibit micrographia, abrupt changes in direction, lack of control, slowness, hesitation, rigidity (causing angular and awkward formations), variability of baseline, variance in control of movement size and speed, and tremor (especially as the disease progresses). While ET exhibits tremor during an action writing task, it may not be present throughout the handwriting pattern. While these qualitative observations are useful, adaptation of subjective ordinal scales could help document examiners quantify more precisely dynamic information such as tremor amplitude and/or frequency from static handwriting samples. Further, research comparing objective handwriting measurements with subjective ordinal rankings made by document examiners could define the accuracy with which document examiners observe dynamic handwriting features.

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Figure 1. PD patient's handwriting illustrating changes in direction and baseline variability.

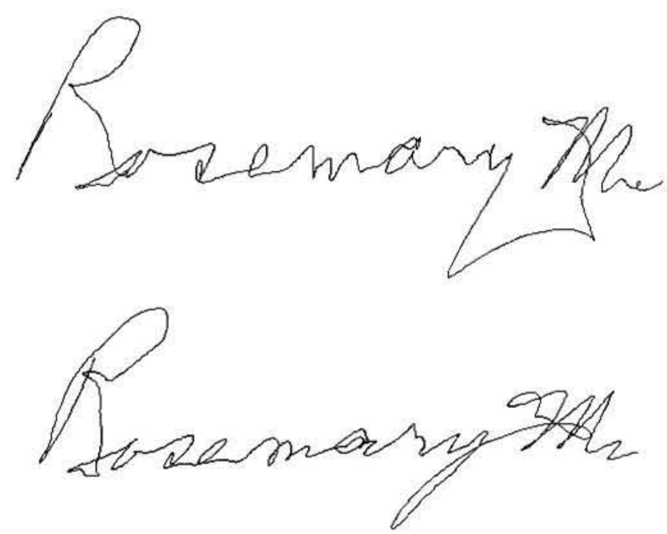

Figure 2. Two examples of a PD patient's handwriting (including recorded airstrokes) illustrating angular and awkward movements.

Figure 3. Signature and handwriting sample of PD patient exhibiting micrographic forms and variance in size.

Figure 4. Handwriting sample of 82 year old woman diagnosed with essential tremor. The writer takes one medication, but claims it does not help the handwriting tremor. The patient has discontinued writing. She can occasionally sign a signature, but typically has others sign for her. The sample exhibited very heavy writing pressure.

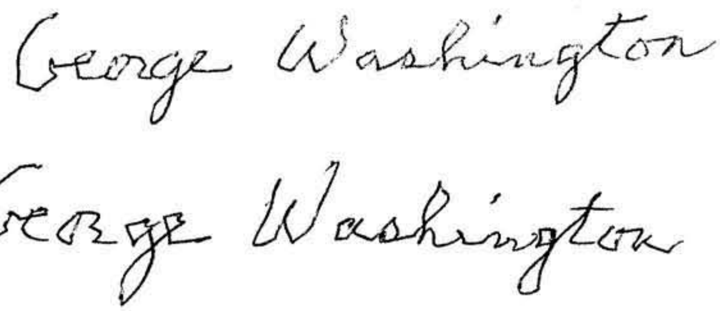

Figure 5a-b. Handwriting samples of 74 year old woman diagnosed with benign essential tremor. Writer uses no medication and does not drink alcohol. Writer was diagnosed over 20 years ago and the condition has gradually worsened. The condition varies, but tends to worsen with stress. The writer described the top writing sample (Figure 5a) as "not as bad as it is sometimes." A second sample was provided three months later showing increased tremor. Both samples exhibited heavy writing pressure.

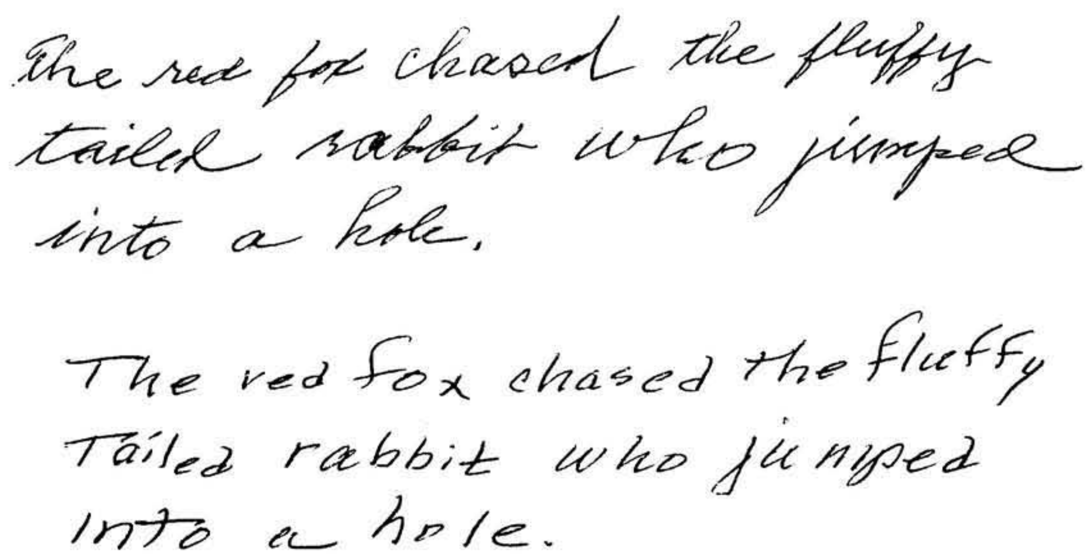

Figure 6. Handwriting and hand printing sample of elderly woman diagnosed with essential tremor. Note that the tremor occurs in some letter formations while other letters are written in a smooth and fluent manner. The tremor is more pronounced in the cursive writing sample. The sample exhibited heavy writing pressure.

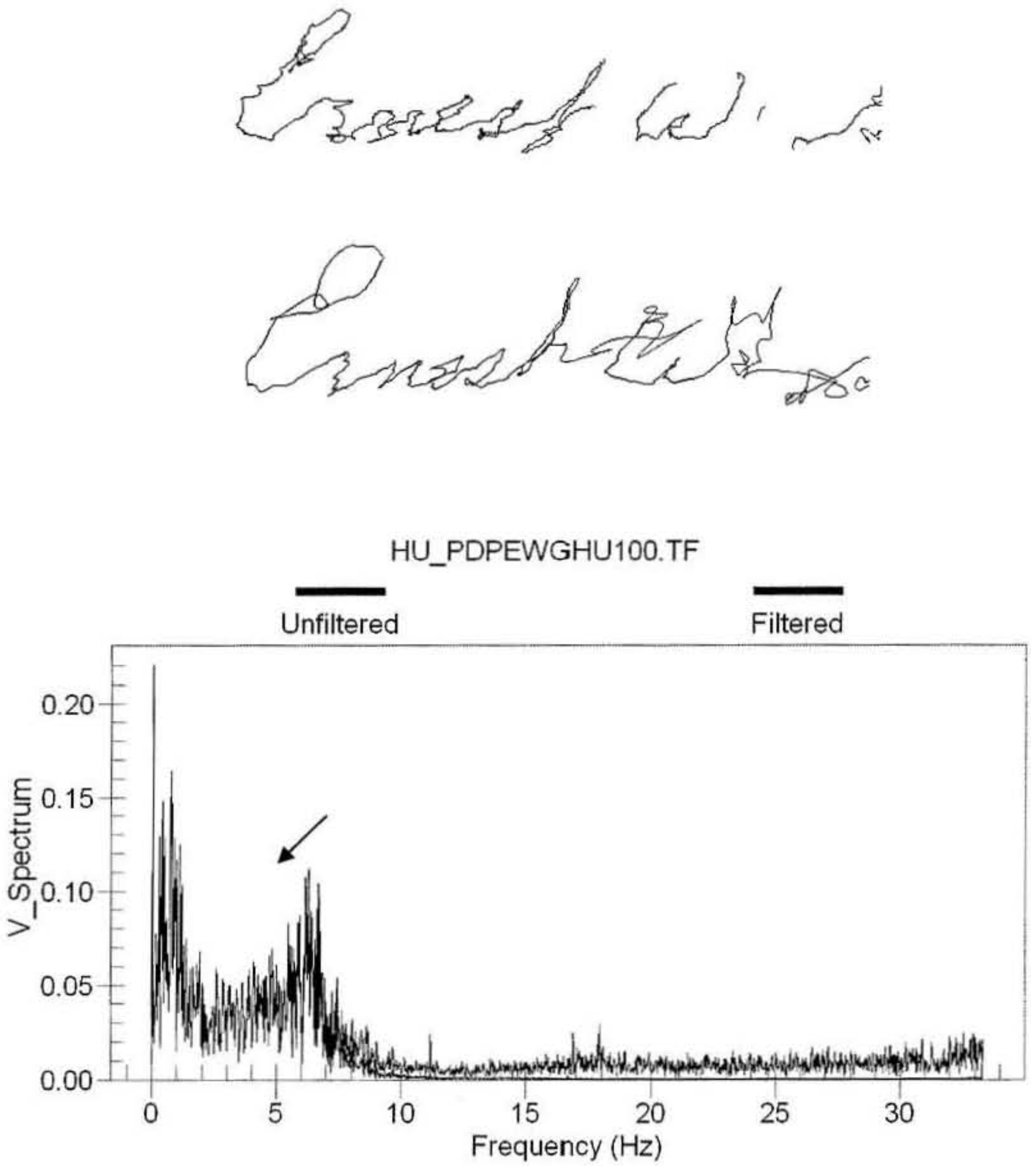

Figure 7. This PD patient manifests extreme tremor in action and rest. The second sample exhibits the tremor in the recorded airstrokes. A frequency spectrum reading indicates the tremor is approximately 6.0 Hz.

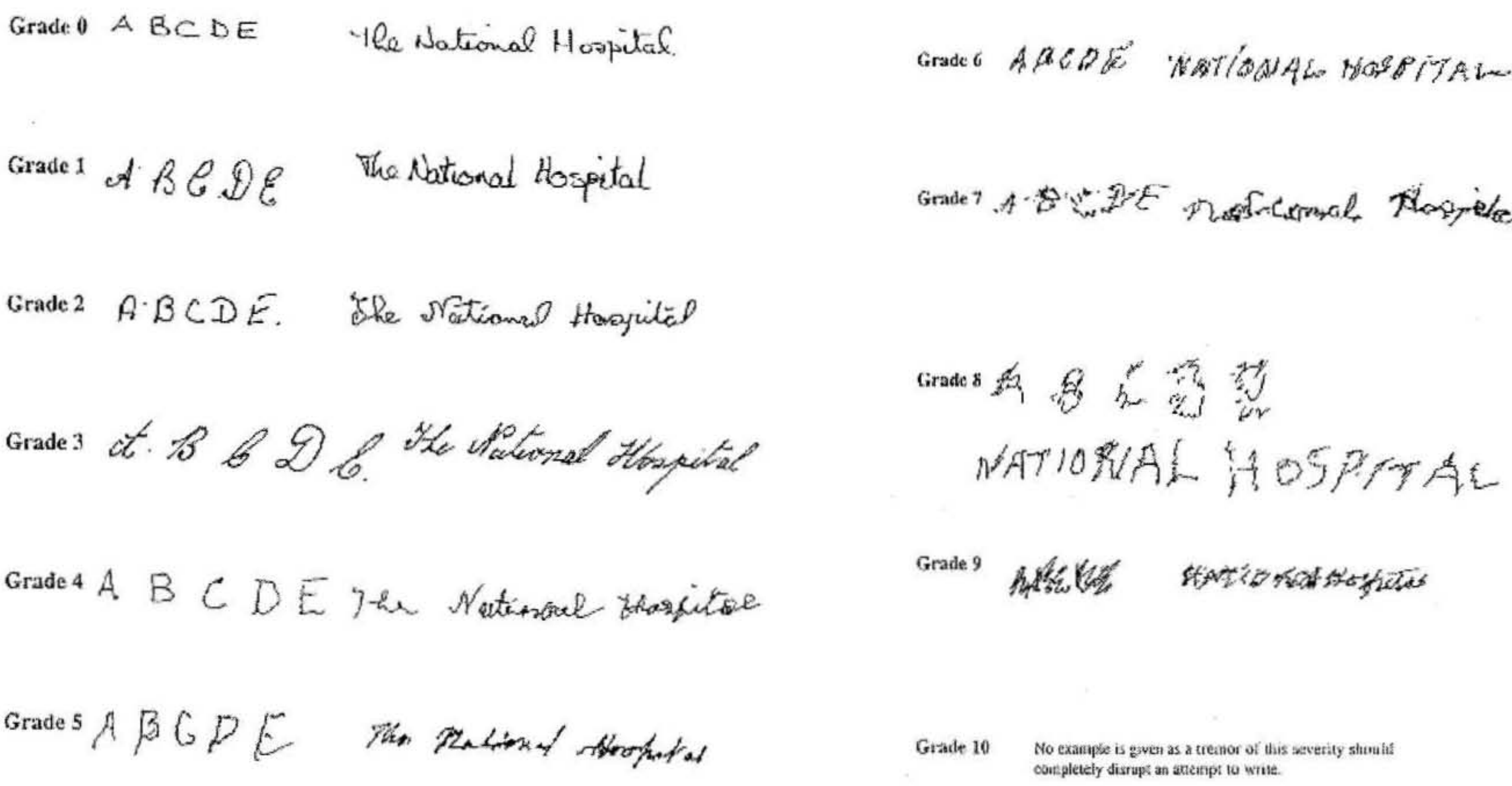

Figure 8. From *Standards in Neurology: Series A: Assessment, Diagnosis and Evaluation: Book I: Assessing Tremor Severity* (p. 20-21), by P. G. Bain and L. J. Findley, 1993, London: Smith-Gordon. Copyright 1993 by Smith-Gordon and Company Limited. Reprinted with permission.

GLOSSARY OF TERMS

compiled by
Heidi H. Harralson, CDE, BC-BFDE

Accelerometer - an instrument for measuring acceleration or for detecting and measuring vibrations (Merriam-Webster Medline Plus Medical Dictionary, 2005)

Akinesia – 1) poverty of spontaneous movement or associated movement; 2) a lack of activity or volition, seen in a slowness in the initiation of movement (Berardelli et al., 2001, p. 2131; Phillips et al., 1991, p. 302)

Amplitude – 1) the extent or range of a quality, property, process, or phenomenon: as a : the extent of a vibratory movement (as of a pendulum) measured from the mean position to an extreme b : the maximum departure of the value of an alternating current or wave from the average value (Merriam-Webster Medline Plus Medical Dictionary, 2005)

Apraxia - loss or impairment of the ability to execute complex coordinated movements without muscular or sensory impairment. (Merriam-Webster Medline Plus Medical Dictionary, 2005)

Basal ganglia – a region located at the base of the brain composed of four clusters of neurons, or nerve cells. This area is responsible for body movement and coordination. (Brennfleck Shannon, J., 2003, p. 571).

Bradykinesia – 1) slowness of movement frequently manifested in Parkinson's disease but can be associated with other diseases; 2) a slowness in the execution of movement and rapid fatigue of movement (Berardelli et al., 2001; Phillips et al, 1991, p. 302).

Bradyphrenia – slowness of thought (Berardelli et al., 2001, p. 2133).

Cerebellum - a large dorsally projecting part of the brain concerned especially with the coordination of muscles and the maintenance of bodily equilibrium, situated between the brain stem and the back of the cerebrum and formed in humans of two lateral lobes and a median lobe (Merriam-Webster Medline Plus Medical Dictionary, 2005)

Corpus striatum - either of a pair of masses of nerve tissue which lie beneath and external to the anterior cornua of the lateral ventricles of the brain and form part of their floor and each of which contains a caudate nucleus and a lentiform nucleus separated by sheets of white matter to give the mass a striated appearance in section (Merriam-Webster Medline Plus Medical Dictionary, 2005)

Cortex – Part of the brain responsible for thought, perception, and memory (Brennfleck Shannon, J., 2003, p. 571).

Dopamine - a monoamine $C_8H_{11}NO_2$ that is a decarboxylated form of dopa and occurs especially as a neurotransmitter in the brain and as an intermediate in the biosynthesis of epinephrine (Merriam-Webster Medline Plus Medical Dictionary, 2005)

Dysgraphia - impairment of the ability to write caused by brain damage. (Merriam-Webster Medline Plus Medical Dictionary, 2005)

Dyskinesia - Impairment of voluntary

movements resulting in fragmented or jerky motions (as in Parkinson's disease) (Merriam-Webster Medline Plus Medical Dictionary, 2005)

Dystonia – Involuntary motor activity which is terminated with sustained contractions at the end of the movement; frequently twisting in character; sometimes the sustained contraction is present only while the affected body part is active (Joseph & Young, 1992, p. 155)

Essential tremor - a common usually hereditary or familial disorder of movement that is characterized by uncontrolled trembling of the hands and often involuntary nodding of the head and tremulousness of the voice, that is exacerbated by anxiety and by activity, that is not associated with Parkinson's disease or any other known disease, and that responds to treatment with propranolol. (Merriam-Webster Medline Plus Medical Dictionary, 2005)

Grapheme – a minimal unit of a writing system; a unit of a writing system consisting of all the written symbols or sequences of written symbols that are used to represent a single phoneme.

Graphomotor – *Med.* Pertaining to the muscular movements in writing.

Huntington's disease - a progressive chorea that is inherited as an autosomal dominant trait, that usually begins in middle age, that is characterized by choreiform movements and mental deterioration leading to dementia, and that is accompanied by atrophy of the caudate nucleus and the loss of certain brain cells with a decrease in the level of several neurotransmitters -- called also *Huntington's* (Merriam-Webster Medline Plus Medical Dictionary, 2005)

Hypermetria - a condition of cerebellar dysfunction in which voluntary muscular movements tend to result in the movement of bodily parts (as the arm and hand) beyond the intended goal (Merriam-Webster Medline Plus Medical Dictionary, 2005)

Hypokinesia – slow movements that are also smaller than desired as in the micrographia of patients' handwriting (Berardelli et al., 2001, p. 2131)

Hypometria - a condition of cerebellar dysfunction in which voluntary muscular movements tend to result in the movement of bodily parts (as the arm and hand) short of the intended goal (Merriam-Webster Medline Plus Medical Dictionary, 2005)

Kinesthesia - a sense mediated by end organs located in muscles, tendons, and joints and stimulated by bodily movements and tensions; *also* : sensory experience derived from this sense (Merriam-Webster Medline Plus Medical Dictionary, 2005)

Kinematics – The geometry of motion of parts of the body, specifically their positions and derivatives with respect to time (first, velocity; second, acceleration; third, jerk, etc.) (Wing, Haggard, & Flanagan, 1996, p. 504)

L-dopa - the levorotatory form of dopa that is obtained especially from broad beans or prepared synthetically, is converted to dopamine in the brain, and is used in treating Parkinson's disease-- called also *levodopa.* (Merriam-Webster Medline Plus Medical Dictionary, 2005)

Motor program - Set of commands to the

muscles required for coordinated action (Wing, Haggard, & Flanagan, 1996, p. 504).
Multiple sclerosis - a demyelinating disease marked by patches of hardened tissue in the brain or the spinal cord and associated especially with partial or complete paralysis and jerking muscle tremor. (Merriam-Webster Medline Plus Medical Dictionary, 2005)

Parkinson's disease - a chronic progressive neurological disease chiefly of later life that is linked to decreased dopamine production in the substantia nigra and is marked especially by tremor of resting muscles, rigidity, slowness of movement, impaired balance, and a shuffling gait -- called also *paralysis agitans, parkinsonian syndrome, parkinsonism, Parkinson's, Parkinson's syndrome.* (Merriam-Webster Medline Plus Medical Dictionary, 2005)

Somatosensory Cortex - either of two regions in the postcentral gyrus that receive and process somatosensory stimuli -- called also *somatosensory area, somesthetic area.* (Merriam-Webster Medline Plus Medical Dictionary, 2005)

Spirography - drawing an Archimedes spiral from inside to out with at least five turns. Used to rate tremor severity (Bain & Findley, 1993, p. 9)

Substantia nigra - a layer of deeply pigmented gray matter situated in the midbrain and containing the cell bodies of a tract of dopamine-producing nerve cells whose secretion tends to be deficient in Parkinson's disease

Tardive dyskinesia – a neurological disorder characterized by involuntary uncontrollable movements especially of the mouth, tongue, trunk, and limbs and occurring especially as a side effect of prolonged use of antipsychotic drugs (as phenothiazine) – abbreviation TD (Merriam-Webster Medline Plus Medical Dictionary, 2005)

Thalamus - the largest subdivision of the diencephalon that consists chiefly of an ovoid mass of nuclei in each lateral wall of the third ventricle and serves to relay impulses and especially sensory impulses to and from the cerebral cortex (Merriam-Webster Medline Plus Medical Dictionary, 2005)

Tremor – 1) rhythmical, involuntary oscillatory movement of a body part (consensus statement of the Movement Disorder Society on tremor); 2) rhythmic oscillatory movements which may occur at different frequencies, and which, can be present at rest or during action (Bain, 2002, p. 3; Joseph & Young, 1992, p. 155)

The following tremor definitions from Bain, 2002 (p. 4):

Rest tremor – tremor present in a body that is not voluntarily activated and is completely supported against gravity

Action tremor – any tremor that is produced by voluntary contraction of a muscle. It includes postural, kinetic, intention, task specific, and isometric tremor

Postural tremor – present while voluntarily maintaining a position against gravity.

Kinetic tremor – tremor occurring during any voluntary movement

Intention tremor – tremor during target directed movement is present when tremor amplitude increases during visually guided movements towards a target at the termination of that movement, when the possibility of position specific tremor or postural tremor produced at the beginning and end of a movement has been excluded

Task specific tremor - kinetic tremor may appear or become exacerbated during specific activities. Occupational tremors and primary writing tremor are examples of this

Isometric tremor – tremor occurring as a result of muscle contraction against a rigid stationary object.

Wilson's disease - a hereditary disease that is characterized by the accumulation of copper in the body (as in the liver, brain, or cornea) due to abnormal copper metabolism associated with ceruloplasmin deficiency, that is determined by an autosomal recessive gene, and that is marked especially by liver dysfunction and disease and neurologic or psychiatric symptoms (as tremors, slowness of speech, inappropriate behaviors, or personality changes) -- called also *hepatolenticular degeneration.* (Merriam-Webster Medline Plus Medical Dictionary, 2005)

Writer's cramp - a painful spasmodic cramp of muscles of the hand or fingers brought on by excessive writing -- called also *graphospasm.* (Merriam-Webster Medline Plus Medical Dictionary, 2005)

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ANNOTATED BIBLIOGRAPHY

Motor Disorders and Handwriting

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PARKINSON'S DISEASE

Bain, P. G. (2002). The management of tremor. *Journal of Neurology, Neurosurgery, and Psychiatry, 72,* 3-9.

Article provides a comprehensive overview of various tremor types including causes and treatment. The author begins the article with a definition of tremor "as a rhythmical, involuntary oscillatory movement of a body part" (p. 3). This definition comes from a consensus statement from the Movement Disorder Society on tremor. The remaining article is equally clear and understandable in explaining the causes and manifestation of tremor types. It provides clear definitions as to phenomenological and aetiology classifications of tremor. It is probably one of the most useful reviews of tremor available as it is organized in the way it categorizes tremor types. Illustrated with references.

Berardelli, A., Rothwell, J. C., Thompson, P. D., & Hallett, M. (2001). Pathophysiology of bradykinesia in Parkinson's disease. *Brain, 124,* 2131-46.

Authors define bradykinesia as slowness of movement and attribute it as one of the primary symptoms of Parkinson's disease. There is also preliminary discussion as to how bradykinesia is related to akinesia and hypokinesia as well as how the three differ. Basal ganglia dysfunction is the primary cause for PD and bradykinesia, but other factors are related as well such as "muscle weakness, rigidity, tremor, movement variability, and slowing of thought" (p. 2132). Weakness in muscle groups contributes to slowness of movement (p. 2132). The authors state "that the role of rigidity in bradykinesia has yet to be proven conclusively" (p. 2132). Rest and action tremor contribute to prolonged reaction times, slow the initiation of movement, and affect pacing the speed of voluntary alternating movements (p. 2132). Movement variability in PD contributes to less accurate movements than normal, particularly when moving fast (p. 2133). Bradyphrenia could contribute to slowness of thought, interfering with movement planning, and increasing reaction time (p. 2133). Overall, the authors theorize that the primary cause for bradykinesia is related to "insufficient recruitment of muscle force during the initiation of movement" (p. 2141). There is discussion about types of surgery and treatments for PD and bradykinesia. This is an in-depth, detailed study of bradykinesia, its associated symptoms (that are carefully defined and broken down), causes, and possible treatments. The authors clearly support their theory as to the possible causes of bradykinesia. Illustrated with references.

Hristova, A. H., & Koller, W. C. (2000). Early Parkinson's disease: What is the best approach to treatment. *Drugs & Aging, 17*(3), 165-81.

Article discusses various treatments for PD that is dependent on the stage of the disease and age of the patient. The authors present information regarding early and advanced stages of PD. Handwriting can be used as a factor in diagnosing PD before onset. A diagnosis of PD

requires two of three symptoms: tremor, bradykinesia, and rigidity. There is some information presented on how to differentiate PD from ET. The focus is on drug treatment and there is a detailed discussion on the effectiveness of various drugs, side effects, and some information on how it could impact motor movements. Although pharmacological treatments tend to improve PD symptoms, the treatments do not totally eliminate all PD symptoms. The article is especially useful for understanding the various pharmacological treatments and it is presented in an organized and easy to follow format. Includes tables and extensive references (five pages).

Longstaff, M. G., Mahant, P. R., Stacy, M. A., Van Gemmert, A. W. A., Leis, B. C., & Stelmach, G. E. (2003). Discrete and dynamic scaling of the size of continuous graphic movements of parkinsonian patients and elderly controls. *Journal of Neurology, Neurosurgery, and Psychiatry, 74*, 299-304.

In testing PD patients with micrographia against age-matched controls, the authors found that PD writers could increase the size of their writing tasks (circles and spirals), but movement variability also increased. The authors state that "it could be that the observed impairments are not attributable to an inability to produce movements of a particular size and speed, but that size/speed reduction is an adaptive strategy used to minimise unwanted variability" (p. 299). It was discussed how increasing size and movement can produce an illegible, messy handwriting "accompanied by a marked disturbance in word construction, including errors of letter formation and word orientation" (p. 304). In exploring the causes of movement variability in PD patients, the authors state that it could be attributed to "the production and maintenance of muscle forces" and "the coordination of muscle joints" (p. 303). The author provides alternative explanations for the causes of writing movement variability that is well-supported by other literature and the results of their study. Includes graphs, charts, and 32 references.

Marinus, J., Visser, M., Stiggelbout, A. M., Rabey, J. M., Martinez-Martin, P., Bonuccelli, U., Kraus, P. H., & van Hilten, J. J. (2004). A short scale for the assessment of motor impairments and disabilities in Parkinson's disease: The SPES/SCOPA. *Journal of Neurology, Neurosurgery, and Psychiatry, 75*, 388-95.

This study tested the reliability and validity of the SPES/SCOPA scales for outcomes in PD. 85 patients were used in the study and raters performed motor evaluation of the patients. It was concluded that "the SPES/SCOPA is a short, reliable, and valid scale that can adequately be used in both research and clinical practice" (p. 388). There was little specific information related to handwriting impairment in the article. References.

Pal, P. K., Samii, A., & Calne, D. B., (2002). Cardinal features of early Parkinson's disease. In *Parkinson's disease: Diagnosis and medical management*. Medical Publishing, Inc., 41-56.

The authors discuss how PD is not a single entity but represents a syndrome and that parkinsonism is part of other neurodegenerative disorders (p. 41). The authors distinguish between idiopathic Parkison's disease and parkinsonism. The syndrome is comprised of: tremor, rigidity, and akinesia (p. 41). It was

noted that almost all elderly people have at least one symptom of parkinsonism (p. 41). In early PD, there is a "deterioration in handwriting, in the form of a gradual decrease in the size of letters (micrographia)" (p. 43). "Approximately 70% of patients notice tremor as the first symptom" (p. 43). The tremor is characterized as "pill-rolling" and "has varying amplitude" (p. 43). The authors also provide details on rigidity and bradykinesia. There is a useful chart which explores differential diagnosis of idiopathic parkinsonism over 10 disorders. Bradykinesia and rigidity were present in varying degrees in all of the disorders while resting tremor was clearly present in only two (variable in four). The study provides three categories in determining idiopathic parkinsonism. It offers a broad overview of PD, but it is especially useful for understanding differential diagnosis and the specific details in diagnosing each disorder. There are several useful charts and 163 references.

Phillips, J. G., Stelmach, G. E., & Teasdale, N. (1991). What can indices of handwriting quality tell us about Parkinsonian handwriting? *Human Movement Science, 10,* 301-14.

The handwriting of seven young, seven elderly, and seven non-tremorous patients with PD were compared on a digital tablet in order to characterize deficits in PD handwriting. There is an analysis of micrographia and the difficulties of writing with PD. The authors also compare pattern-based movements versus trajectory-based movements. The results of the study showed that PD patients "had significantly more changes both in the direction and in the rate of acceleration relative to the velocity function, than did control subjects" (p. 309). The authors state "irregularities in velocity and acceleration functions were not simply due to Parkinsonism tremor, and are probably due to problems developing and maintaining movement forces" (p. 310). The authors present a different theory regarding the influence of tremor in PD handwriting and give an example of a PD patient who was measured with severe tremor even though the handwriting did not exhibit tremor. The study probably needs to be replicated with the use of more subjects. Illustrated with tables and handwriting examples. Includes 26 references.

Oliveira, R. M., Gurd, J. M., Nixon, P., Marshall, J. C., & Passingham, R. E. (1997). Micrographia in Parkinson's disease: The effect of providing external cues. *Journal of Neurology, Neurosurgery, and Psychiatry, 63,* 429-33.

The authors test 11 PD patients and 14 control subjects to determine if external cues can increase the amplitude or size of handwriting in PD patients with micrographia. It was found that "letter size increased significantly when either they were given visual targets or constant auditory reminders" and "...the effects of training persisted even when the patients wrote without external cues" (p. 432). By directing the patient's attention to the task, it was found that amplitude increased. The authors also suggest that external cues can be helpful in "speeding the initiation of movement" as well (p. 433). This study clearly illustrates how more conscious attention directed to a task by a PD patient can cause changes in the handwriting. Illustrated with charts and graphs. 36 references.

Shulman, L. M., Wen, X., Weiner, W. J., Bateman, D., Minagar, A., Duncan, R., & Konefal, J. (2002). Acupuncture therapy for the

symptoms of Parkinson's disease. *Movement Disorders, 17*(4), 799-802.

This non-blind pilot study tested 20 PD subjects on the effectiveness of acupuncture therapy. Apparently, use of acupuncture by PD patients is significant as 40% of PD patients use alternative therapies and acupuncture was the third most frequent therapy used (p. 799). However, research on its effectiveness has been limited (p. 800). Objective assessments indicated that only sleep and rest showed improvement. A subjective questionnaire completed by the patients indicated that areas including tremor and handwriting were improved, especially in patients with more severe symptoms. Obviously, more research needs to be done in this area. Additionally, from a handwriting examination perspective, it would be helpful to know exactly in what way handwriting was improved by the acupuncture treatments. Includes tables and 17 references.

Teulings, H-L., Contreras-Vidal, J. L., Stelmach, G. E., & Adler, C. H. (2002). Adaptation of handwriting size under distorted visual feedback in patients with Parkinson's disease andelderly and young controls. *Journal of Neurology, Neurosurgery, and Psychiatry, 72,* 315-24.

The study examined the results of handwriting of both PD patients and healthy control subjects when presented with distorted feedback of their handwriting on a monitor while they were writing. The control subjects were able to adapt to the distorted visual feedback and this adaptation was reflected in their handwriting movements. The PD patients relied on the static trace instead of the distorted feedback from the monitor and did not adapt in a way that the control subjects did. The authors point out that a previous study had different results and recommend that the study be replicated. The authors also present two possible hypotheses for the causes of micrographa in PD: 1) "patients with Parkinson's disease produce only slightly smaller strokes than they programmed—for example, due to reduced motor output or weakness of the agonist force—and fail to discover this discrepancy—for example, due to their reduced kinaesthesia—and programme the following strokes to match the visible stroke size (and not the intended sizes) of the previous, undersized strokes. Recursively repeating this process yields a progressive reduction of writing size as found in parkinsonism micrographia" (p. 323). 2) "patients with Parkinson's disease attempt to match their actions with their perception of the ongoing pen strokes" (p. 323). It was pointed out that the causes of micrographia are not "well understood" (p. 315). Overall, the study provided a detailed analysis of the feedback processes involved in the handwriting of PD patients and helps to explain possible causes of micrographia. Includes charts, graphs, and 35 references.

Teulings, H-L., Contreras-Vidal, J. L., Stelmach, G. E., & Adler, C. H. (1997). Parkinsonism reduces coordination of fingers, wrist, and arm in fine motor control. *Experimental Neurology, 146,* 159-70.

Study investigates the movement coordination of PD patients and elderly control subjects that were given various handwriting tasks to be performed on a digital tablet. There is an explanation of which muscles and parts of the wrist, fingers, and arm are used for various handwriting movements. For example, finger movements perform up/down strokes; wrist flexions and extension produce small left/right

movements; and the forearm produces large left/right movements (p. 159-60). In the actual study, "this research suggests that some of the fine motor control problems in PD patients are caused by a reduced capability to coordinate the fingers and wrist and by reduced control of wrist flexion. The control problems occur in handwriting strokes that require the coordination of wrist and fingers (i.e., strokes in oblique orientations)" (p. 168). This study is especially useful in understanding the biomechanics of handwriting and how dysfunction in biomechanics causes handwriting dysfluency in PD. Additionally, a useful characterization of PD handwriting by another author is cited. Includes charts, graphs, and 43 references.

Van Gemmert, A. W. A., Adler, C. H., & Stelmach, G. E. (2003). Parkinson's disease patients undershoot target size in handwriting and similar tasks. *Journal of Neurology, Neurosurgery, and Psychiatry, 74,* 1502-8.

The authors state that complex handwriting movements are more difficult for PD patients than for healthy controls. The study tested 13 PD patients and 13 age matched controls. As the handwriting size requirements increased, PD patients undershot the target size and the target size was especially undershot when the PD patient were required to produce alternating complex handwriting movements. "These findings support the view that the range in which stroke size can be manipulated without significant changes in stroke duration is smaller in parkinsonian handwriting than in the handwriting of controls, and they support the notion that patients with PD tend to trade off stroke size for stroke duration" (p. 1506). Additionally, the authors note that PD patients "have a reduced ability to modulate forces…and "are impaired in modulating muscle activation and/or muscle force" (p. 1507). From a handwriting characterization perspective, the study gave specific examples of complex handwriting movements that PD patients had difficulty producing especially when increased speed and size were also required. Illustrated with graphs and tables. Includes 32 references.

Van Gemmert, A. W. A., Teulings, H-L., Contreras-Vidal, J. L., & Stelmach, G. E. (1999). Parkinson's disease and the control of size and speed in handwriting. *Neuropsychologia, 37,* 685-94.

PD patients and elderly controls performed writing tasks involving variances in speed and size. "Participants were required to draw repetitive patterns of eight strokes; i.e. forward slanted, back-and-forth strokes, backward slanted, circles drawn counterclockwise, and the cursive pattern 'llll'" (p. 686). It was found that PD patients can write quickly and can increase the size of their handwriting. However, "PD patients were unable to double their stroke size when instructed [which] reflects a reduced capability to maintain a constant force amplitude over an entire stroke" (p. 692). There is a diagram of a network model for basal ganglia control of movement in normal and PD conditions along with a detailed explanation of the model which is helpful in understanding the mechanics involved in PD handwriting. Includes diagrams, charts, and 45 references.

ESSENTIAL TREMOR

Biary, N., & Koller, W. (1987). Kinetic predominant essential tremor: Successful treatment with clonazepam. *Neurology, 37,* 471-4.

The authors studied a variant of essential tremor (kinetic predominant tremor) using 14 patients exhibiting marked kinetic tremors of long durations. Some of the patients remarked that they had a reduction in tremor "with ingestion of alcohol" (p. 471). The level of tremor was quantified using a five point scale (0-4) and use of an accelerometer. "Mean frequency of kinetic tremor was 4.6 Hz (range, 3.6 to 6.0)" (p. 472). The authors state that "essential tremor affects mainly the upper extremities and is maximal in the hands...kinetic tremor is responsible for functional disabilities" (p. 473). Both alcohol and propranolol had the effect of decreasing the kinetic tremor of essential tremor. The authors also state that "the pathophysiology of essential tremor is unknown" but CNS dysfunction may be a cause (p. 473). Study helps to differentiate kinetic tremor from postural tremor. Two handwriting examples of patients (before and after treatment) are included along with graphs, charts, and 19 references.

Cohen, L. G., Hallett, M., & Sudarsky, L. (1987). A single family with writer's cramp, essential tremor, and primary writing tremor. *Movement Disorders, 2*(2), 109-16.

This case study involves a family that had two members with essential tremor, a set of twins with writer's cramp (highly unusual), one with essential tremor and writer's cramp, one with primary writing tremor, and one with uncharacterized tremor. It is known that essential tremor can be genetically inherited, but the study also discussed the possible genetic causes of other types of motor disorders. The connection between essential tremor and dystonia was also mentioned. Detailed background information was provided on each family member including problems with handwriting. Accelerometer graphs were provided including 22 references.

Elble, R. J., Sinha, R., & Higgins, C. (1990). Quantification of tremor with a digitizing tablet. *Journal of Neuroscience Methods, 32*, 193-8.

Methods used to quantify tremor are discussed including subjective scales that do not provide "precise measures of tremor amplitude and frequency" and accelerometers which can be sensitive and versatile, but in order "to measure all components of tremor, at least 6 one-dimensional accelerometers are needed" (p. 193). Digital tablets are also more efficient and economical than accelerometers. A detailed explanation of how digital tablets work is provided. In the study, 6 normal subjects and 12 ET patients did handwriting exercises on the digital tablet. "Physiological hand tremor has a peak-to-peak amplitude of less than 0.5 mm and given the accuracy and resolution of our tablet, it is understandable that physiologic tremor could not be measured on the tablet. By contrast, we found that even mild pathologic tremor (peak-to-peak amplitudes of 1.0 mm or greater) was consistently recorded" (p. 195). This is an introduction to the uses of the digital tablet in quantifying tremor. Many advances have been made in this area since the article was published in 1990. Graphs and two examples of Archimedes spirals by a normal subject and one with ET are provided. Includes 12 references.

Elble, R. J., Brilliant, M., Leffler, K., & Higgins, C. (1996). Quantification of essential tremor in writing and drawing. *Movement Disorders, 11*(1), 70-8.

The study compares the handwriting taken with a digital tablet to samples recorded with the accelerometer of 87 patients with ET. Simple

ordinal rating scales for writing are more effective in assessing clinical impairment than the accelerometer, but they offer little to no information in quantifying tremor amplitude and frequency and "tremor frequency is of particular interest in mechanistic studies of essential tremor" (p. 70). "Hand tremor and writing tremor usually produced a distinct peak in the acceleration spectrum" (p. 72). A four point (0-3) subjective tremor rating scale was used to estimate the tablet measurements. ET "begins insidiously and is initially very mild" (p. 73). In comparing the subjective scale with the results from the digital tablet, it was found that "grade 0 tremor never produced a spectral peak"...inconsistent grade 1 tremor "produced no spectral peak"..."grade 2 tremor generated prominent spectral peaks"...and some with "grade 3 tremor could not keep their pens on the tablet" (p. 72-73). The study found that "tremor frequency often increased during writing and drawing when the postural tremor frequency was <7 Hz" (p. 78). Overall, the study found that "the digitizing tablet is a useful and relatively inexpensive tool" (p. 78). This study is particularly useful in evaluating different methods for quantifying tremor. Includes graphs, tables, and 12 references.

Kachi, T., Rothwell, J. C., Cowan, J. M. A., & Marsden, C. D. (1985). Writing tremor: Its relationship to benign essential tremor. *Journal of Neurology, Neurosurgery, and Psychiatry, 48,* 545-50.

Nine patients with writing tremor were studied. The patients had tremor frequency ranging from 5-6 Hz. The results were compared to previous studies on essential tremor. The authors state that primary writing tremor is related to benign essential tremor. "In all cases, the principal feature was a rhythmic pronation/supination of the forearm, which in eight cases had the "sinusoidal" character of a true tremor; in the other two cases, the movement appeared more jerky" (p. 547). In one patient, tremor only occurred as the writing act started and then disappeared as the writing continued. Some patients noted that alcohol improved the tremor. There were "rhythmic bursts at 5 to 6 Hz when the patients began to write" (p. 547). Injections of propranolol were investigated and it was discovered that in some patients writing was improved and the amplitude of tremor bursts decreased (p. 549). In differentiating the cause of tremor, the authors ask: "is the jerky tap-provoked tremor (which was originally designated "primary writing tremor") a different entity from the continuous tremor that persists throughout the act of writing?" (p. 549). However, the authors noted that it was probably a variant of benign essential tremor. The authors also note the symptomatic differences between PWT and writer's cramp. This study aids in understanding the causes of various motor disorders. Includes handwriting/drawing illustrations, graphs, charts, and 19 references.

Koller, W., Biary, N., & Cone, S. (1986). Disability in essential tremor: Effect of treatment. *Neurology, 36,* 1001-4.

The authors state that ET "is the most common movement disorder, but it is poorly understood" (p. 1001). 18 patients treated with propranolol and primidone were studied. Handwriting improved with therapy. A blind rater rank ordered the handwriting samples (both treated and untreated) from best to worse and "the worst specimen occurred more frequently in the untreated condition" (p. 1003). In interviewing

the patients, it was found that "writing a signature was a common problem, particularly in public, and most patients had discontinued all activities that involved writing" (p. 1002). The authors pointed out that although ET is frequently called "benign" that the embarrassment associated with tremor causes significant social embarrassment and has even resulted in job losses for some patients. There is one comparative example of a patient's writing/drawing before and after treatment. Includes charts, graphs, and 20 references.

Martinelli, P., Gabellini, A. S., Gulli, M. R., & Lugaresi, E. (1987). Different clinical features of essential tremor: A 200-patient study. *Acta Neurol, 75,* 106-11.

200 patients were studied in order to determine the different clinical features of ET. Tremor was the major symptom. Tremor was defined as mild, moderate, and severe. "A family history of tremor was reported by 40% of the patients" (p. 107). Most of the patients studied had typical ET. The upper limbs were the most affected by tremor. There was little specific information related to handwriting in this study, however, it was useful in presenting information related to the different ways in which ET can manifest. Includes charts and 38 references.

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Micrometry Using a Calibrated Ocular Reticule

by

Emily J. Will, CDE and Joseph Barabe, Senior Research Microscopist

Micrometry is the measurement of small features using a microscope. Most microscope eyepieces can accommodate a reticule, which is a built-in measuring device with rulings that appear transparently over the image being viewed. A reticule is placed at the focal plane of the ocular, or eyepiece, so that the reticule and the subject are in focus at the same time. An example of a typical linear reticule is shown in figure 1.

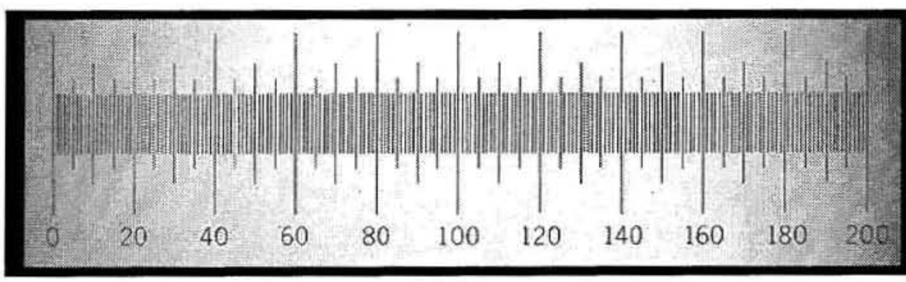


Figure 1 – Reticule

Using the reticule, the size of an area of interest in a particular handwriting, such as the thickness of an ink line, or the inner diameter of an eyelet, can be measured with great precision. Notice, however, that the reticule, while marked off into specific divisions, does not contain any unit of measurement. Why is that, and how do we report measurements without a unit of measure assigned to the reticule itself?

The reason there is no unit of measure included is that, depending on the specifics of a particular optical system, the dimensions represented by the rulings can vary. When using the same reticule with different levels of magnification in the same device, the absolute value of the divisions of the reticule must be calibrated for each level of magnification. This phenomenon will be demonstrated in this article.

Calibration is important because, if two observers are using different equipment, or even different magnifications, they might report different results simply because their optical devices are not calibrated to a standard. Also, during testimony, a reasonable question might be, "To what extent are your measuring devices accurate, and how have you verified their accuracy?"

Microscope reticules can be easily calibrated using a simple, but highly precise device – a stage micrometer. A stage micrometer is essentially a glass slide marked off into numbered segments, in a careful manufacturing process that insures the precision of the divisions. In actuality, there are levels of stage micrometers available, the most expensive of which have been through a certification process by a standard-setting organization.

The stage micrometer referenced in this article is the S8 Stage Micrometer manufactured in England by PYSER-SGI LTD (Figure 2). The

measurement scale is inside the circle with the crosshairs at the center of the slide. Diamond cutting tools and a special ruling engine allow for precision in the manufacturing process. The literature states:

> *These stage graticules* (reticules) *are intended for the routine calibration of eyepiece patterns, particularly when alternating between objectives on one microscope or when using the same graticule in different microscopes. Their robust construction makes them ideal for student use and for instructional purposes. The scale or grid is centered on a glass disc mounted in a black anodised aluminium slide 75mm x 24mm x 2mm thick.*

would not typically be found in a document examination laboratory.

A few words about measurement units will be helpful. The distances involved in microscopic measurement and calibration are very small, and require prefixes such as "milli" and "micro."

- Milli (m) – One thousandth (1/1,000th) – the unit is one millimeter (mm)
- Micro(µ) – One millionth (1/1,000,000th) - the unit is one micrometer (µm)

Therefore, one thousandth of a millimeter = 1 micrometer. Restating mathematically, 0.001 mm = 1µm and, conversely, 1 mm = 1000 µm

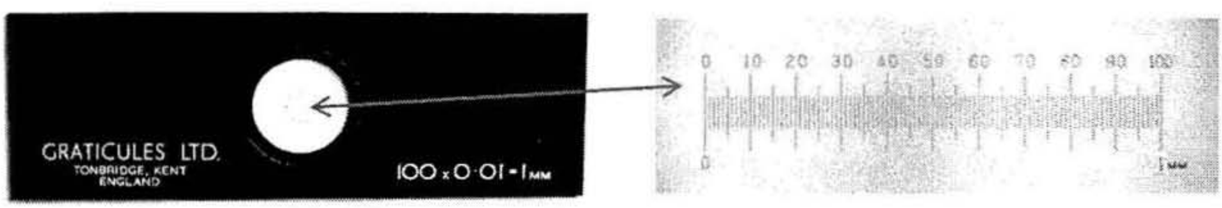


Figure 2 – The stage micrometer

Two types of stage micrometer are available – one for transmitted light and one for reflected light. Either type can be used, depending on the illumination type of your microscope. For calibrating microscope reticules, the transmitted light micrometer is often most appropriate because light travels through the reticule as it travels through the microscope tube to the human eye. Reflected light stage micrometers are used with axial reflected light illumination, generally found in metallurgical microscopes. Reflected light stage micrometers usually have a special, highly reflective metallic finish, and

The term micrometer (µm) will be used in the following discussion, and again, each micrometer equates to 1 thousandth of a millimeter.

The S8 Stage Micrometer line is one (1) millimeter long with one hundred divisions, resulting in a division line every 0.01 mm, or 10 micrometers (µm). Therefore, in every situation using the S8 micrometer, each stage micrometer segment is 10 µm (10 micrometers) in length. The division lines themselves are two micrometers (2µm) wide, and the overall

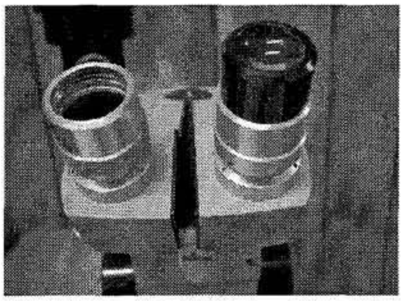
accuracy of the device is within one micrometer (1µm).

The calibration of a reticule is essentially a visual and mathematical process which is accomplished by following specific steps, which were outlined and explained at a workshop entitled "Fundamentals of Microscopy for Forensic Document Examiners" given at the College of Microscopy in Westmont IL in August, 2005. The microscope used in the following demonstrations is an American Optical Document Comparison microscope with 15 X W.F. eyepieces and objectives resulting in powers of 40 X and 20 X; other microscopes will most likely be different.

It will be helpful to remember that the distance between the rulings on the S8 stage micrometer is a fixed distance of 10 µm. The distance represented by the rulings of the ocular reticule has no fixed value – it changes with the optical system and magnification level. The purpose of the calibration is to define that value for each magnification at which the reticule will be used.

Calibration Method

1. The reticule to be calibrated should be installed in the microscope ocular at the focal plane. For our purposes the reticule could be inserted in either the right or left ocular. For this discussion we will assume the left. It is usually simply a matter of unscrewing the eyepiece and inserting the reticule in the allotted location. See Figure 3.
2. Bring the eyepiece reticule into sharp focus by rotating the eyepiece. Don't adjust the other eyepiece yet.
3. Put the stage micrometer on the microscope stage as if it were a questioned document to be examined.
4. Turn on the light used for trans-illumination.
5. Once the reticule is in place, there are two steps to proper focusing:
    a. Using only the left eyepiece and covering your other eye, achieve a good focus on the subject (in this case, the stage micrometer). At this point the reticule in the left eyepiece and the stage micrometer are focus.



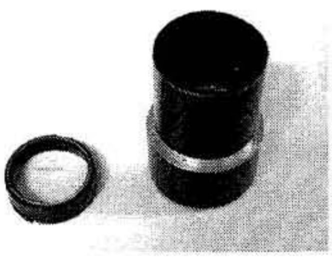


Figure 3 - In most cases one eyepiece of the microscope will have a screw-type (helicoid) focus. That eyepiece can be lifted from the tube, and the reticule can be slipped into a prepared position in the eyepiece. In this example, the left eyepiece is focusable, and a metal ring around the reticule keeps it in position inside the eye tube. For this image, the metal ring and reticule were gently pulled from inside the eyepiece, which is shown upside down.

b. Now cover the left eye and focus the right eyepiece on the stage micrometer, using ONLY the eyepiece focusing screw- not the main microscope focusing knob. Now both eyepieces, the reticule and the stage micrometer are all in focus.

6. Using the highest optical power of the microscope (in this case 40 X), position the stage micrometer so that it matches with one end of the markings of the reticule. See Figures 4 and 5.

7. Observe and record the number of ocular scale divisions of the reticule that are covered by the stage micrometer. In the illustration the 100 rulings of the stage micrometer align with 80 ocular scale divisions of the reticule. See Figures 4-5.

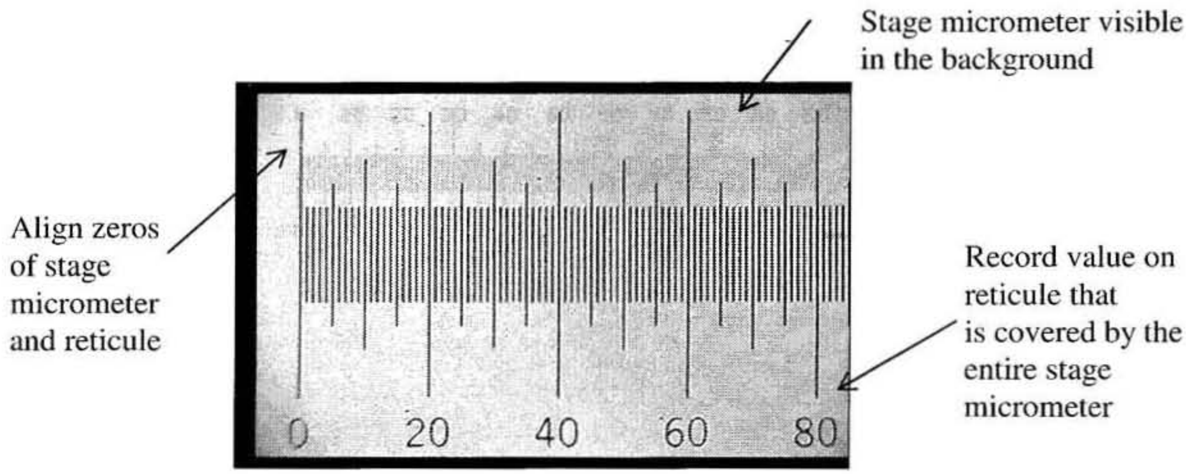


Figure 4 – In the foreground is the optical microscope reticule with its numeric markings along the bottom. In the background at the top are the markings of the stage micrometer. The microscope power is 40 X. We observe that 80 ocular scale divisions (OSDs) of the reticule are required to cover the entire 100 rulings of the stage micrometer.

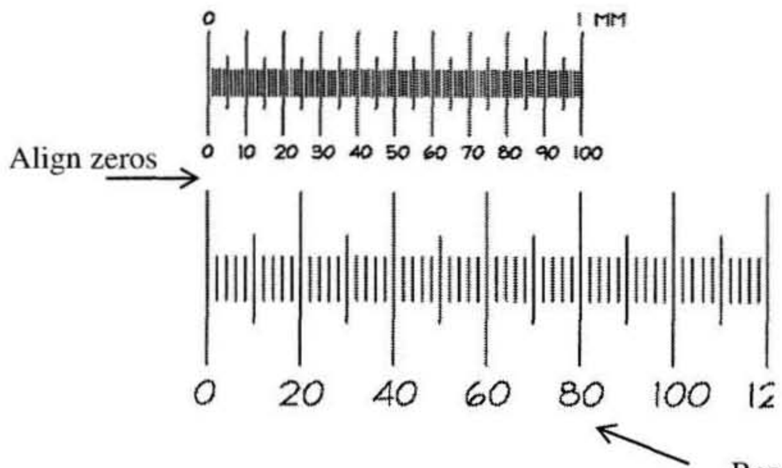


Figure 5 - Capturing images of this procedure is very challenging. This drawn representation is presented for clarification.

7. Use the following mathematical formula to determine the distance between each OSD of the reticule, remembering that the full length of the stage micrometer is 1 millimeter, or 1000 micrometers (μm):

$$1000\ \mu m \div \#\ OSD = \#\ \mu m \text{ per OSD}$$

In English, this translates to 1000 micrometers divided by the number of ocular scale divisions of the reticule covered by the stage micrometer equals the number of micrometers per ocular scale division.

Applying the numbers from the example we are using:

$$1000\ \mu m \div 80\ OSD = 12.5\ \mu m \text{ per OSD}$$

At higher magnifications (when the entire stage micrometer is not visible thought the eyiece) , a more general formula might be useful:

Distance measured by stage micrometer divided by # OSD

We now know that when using the 40 X objective, each division of the optical reticule of this microscope represents a distance of 12.5 μm. If we measure a feature of a handwriting that spans three OSDs, we can report that that feature is 37.5 μm wide (3 divisions, which are 12.5 μm each).

To summarize, the formula determines a relationship between the rulings of the stage micrometer (known) and the reticule (unknown)

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Now consider the same microscope and reticule at a lower level of magnification. See Figure 6.

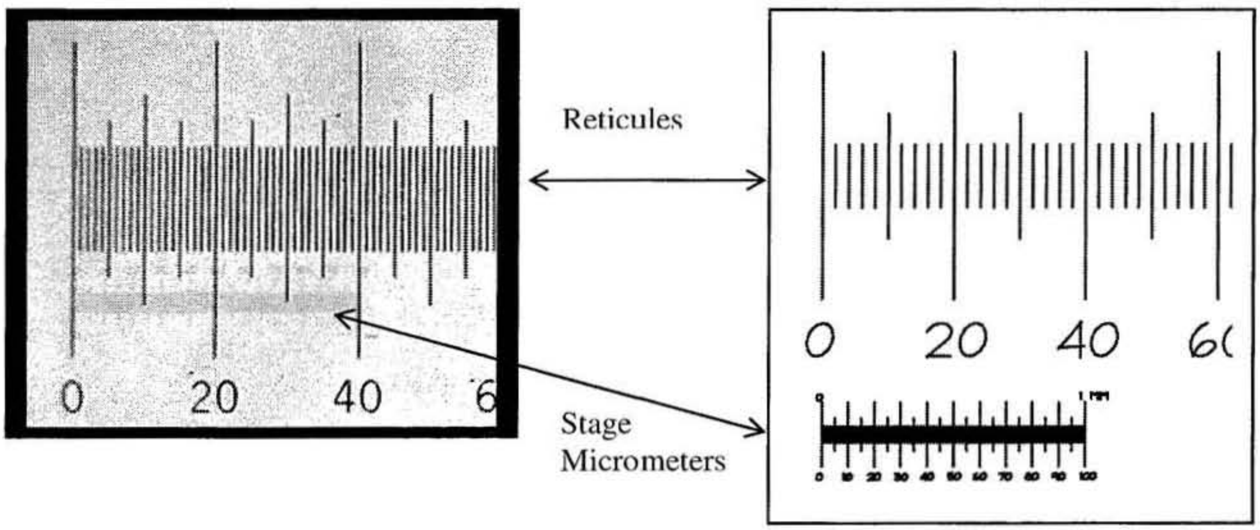

Figure 6 - A photograph and a drawn illustration of the ocular reticule (above) and the stage micrometer (below) at a 20x magnification level. With less magnification it is more difficult to see and photograph the fine divisions of the scale micrometer. At this magnification, the stage micrometer covers 40 divisions of the reticule.

Using the formula stated above,

1000 µm ÷ # OSD = # µm per OSD

1000 µm ÷ 40 OSD = 25 µm per OSD

Now, when using this reticule to make measurements of objects at 20X magnification, the user knows that every reticule division represents 25 µm of distance.

Earlier in the article it was mentioned that the raw distance measured by the optical reticule will not be the same at each level of magnification. Compiling the results of the above two calculations in Table 1 below, we see clearly that this is true.

Table 1
Comparison of calibration information

American Optical Microscope Power (eyepiece x objective)	Distance between Reticule Divisions
40x	12.5 µm
20x	25 µm

Clearly, there is an inverse relationship between the power of the microscope and the distances represented by each division of the reticule. As the power decreases by half, the distance has doubled. In general, this type of relationship will be found, but the numbers may not be exact. It is important to calibrate the microscope for each level of magnification and to make note of the results so that the most accurate reporting will result.

The purpose of this article has been to explain the process of calibration of ocular reticules using a stage micrometer. Every document examiner will not necessarily own a stage micrometer, in part because they are costly devices that are usually required one time in the life of any optical device – at the time of calibration. Therefore, as a membership benefit, the NADE Library has purchased the stage micrometer used in the preparation of this article, and will make it available on loan to any NADE member, following the usual library loan policies. Contact the NADE librarian for information.

The authors would like to acknowledge the contribution of the College of Microscopy in presenting this workshop material and its generosity in sharing valuable knowledge with the document examination community.

Emily J. Will is a board certified forensic document examiner located in Raleigh, North Carolina. She is an active member of the Association of Forensic Document Examiners and the National Association of Document Examiners. Ms. Will has a special interested in the technical aspects of document examination, which can be further explored at her website, http://Qdewill.com

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HOLE PUNCH SOLVES THE CASE

by
Kay Micklitz, CDE

An attorney called with a request to check out a Will that had a questionable page and one that the client thought may have had an alteration made and substituted in the Will. The Will consisted of nine (9) pages and the questioned page seven (7) had a space of 4 inches between the last line of typed text and the end of the page. Following the questioned page seven (7), on page eight (8), was the testatrix's signature, witnessed and notarized. The last page of the Will, page nine (9), was the self-proving affidavit.

The original of the Will was examined at the courthouse where it had been filed for probate. The paper was examined for watermarks and no watermark was imbedded in the paper. The paper was a copy-quality 20 lb. bond.

The margins of the text of the Will were measured from top and bottom, right and left sides, paragraph indented lines, double indented margins and right hand justification. The reverse side of the paper was examined using side lighting and evidenced only a single light vertical line impression in the middle of each page that appeared to be a result of the paper manufacturing. This vertical line appeared on the reverse side each of the pages of the Will indicative that all of the pages had come either from the same ream of paper or similar reams of the same quality paper. There were no folds in the pages.

Also, it was noted that the Application for Probate, prepared by the same attorney, had the same quality paper with the vertical line on the reverse side.

The font used was Times New Roman and 12 pitch. The font and pitch were the same for all the pages. The page numbering at the center bottom of each page aligned.

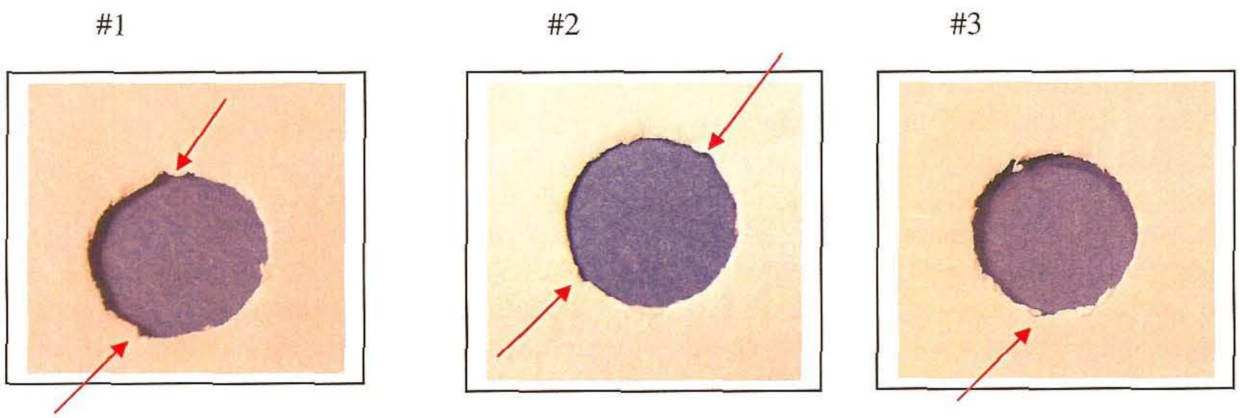
Also, the staple holes in the paper and the size of the staple was measured. There was only one set of staple holes and all the staple holes were aligned. The entire Will had two holes punched in the top of all pages. The two-holes punched at the top were a result of the county clerk's filing procedures.

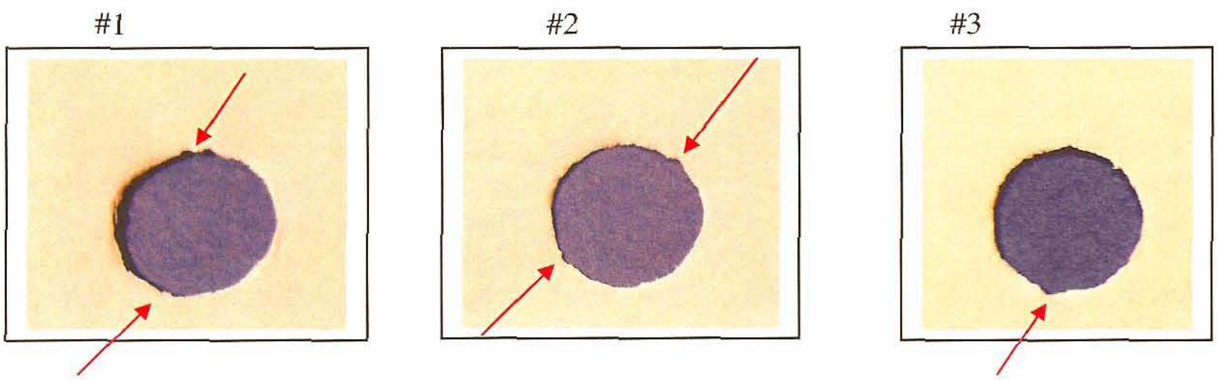
There were no trash marks on any of the pages, either front or back.

There were three holes punched in the left side of all pages of the Will. Pages two and three were out of alignment with page one from the left edge of the paper by one cm; page two was aligned with page three; pages four through nine were aligned but out of alignment with page one. All the holes were 1-1/4 inches from the bottom edge of the page.

The three holes punched on the left side of each page were examined with a hand held magnifier and a macroscope. Magnification revealed that the holes were not clear and crisp as would be expected and as they appeared when visually observed without magnification. With magnification, the three-hole punch appeared to have been rather worn as each hole evidenced tears from the force of the pressure used with the hole punch that aligned with the tears in the holes from the preceding page. All the holes were 6 cm from the left hand edge of the page except page two which was 7 cm from the left

Holes Punched in Page 6





Holes Punched in Page 7

edge of the page. The holes on each page were digitally photographed to illustrate the ragged or tear in the edges.

Page seven (7), the questioned page, with a large space at the bottom of the page, consisted of three paragraphs identified as "D," "E," and "F." Paragraphs "D" and "E" were double indented at the initial line of the paragraph. Paragraph "F" was indented only once.

What was troubling was the extra space at bottom of the text on page seven although there was no allegation of change of disbursement of the decedent's property or disbursement of the property contrary to what had been previously expressed.

The result of the examination did not reveal any evidence of manipulation of the Will, nor insertion of a different page seven (7) having

been inserted in the Will. The use of the same hole punch evidenced that any changes or alterations made to the Will had to have been made in the office of the attorney preparing the Will and using the same three-hold punch.

The client had no allegation of misuse of distribution of property, but the extra space on the one page raised some suspicions. The final analysis with the digital images satisfied the client that there had been no alteration or manipulation of the Will.

Kay Micklitz, CDE, is a board certified document examiner and a Diplomate of NADE. Kay has an extensive background in civil litigation. She joined NADE in 1994 and earned her CDE in 1997. Kay is court qualified and has met and passed a Daubert challenge. She has been appointed by federal, state and county courts as an expert. Kay completed studies through the National Questioned Document Association and the American Institute of Applied Science for Questioned Documents and Police Photography. Kay is a licensed instructor for the Texas police officers and private investigators. She is also a state commission Crime Scene Investigator for Precinct 2, Bexar County, Texas.

AUTHORITIES SPEAK OUT

ON TRACING

by
Kay Micklitz, CDE and
Barbara Downer, CDE

Tracing is a clumsy forgery. Page 326.

Traced writings usually show hesitation, abnormal changes of direction, inconsistent pen pressure and unnatural movement interruptions in a more pronounced manner than simulations. The most common symptom of forgery is this quality of line, pointing toward the manner in which the writing was made. Page 327-328

Natural, free, unconscious writing cannot be produced by the tracing process. Page 329

Albert Osborne, *Questioned Documents*, Nelson-Hall Publishers, Chicago IL, 1929

Authorities on identification of forgery are agreed that no two signatures of an individual written under ordinary circumstances will be identical in all respects, that one signature must be a tracing from a genuine signature or that if two signatures are identical it is conclusive evidence that one was traced or that both were traced from another signature. Page 174

It is negative to sound reasoning that two or more signatures can all be genuine when they superimpose so as to appear identical. Observation and demonstration have verified that two signatures cannot be exactly the same; consequently, one must be a tracing of another signature written by careful intention. Page 175

Frequently the tracing has the character or general appearance of a drawing rather than a piece of writing, and this leads to detection and proof by superimposition. Page 177

J. Newton Baker, *Law of Disputed and Forged Documents,*, The Michie Company, Charlottesville VA, 1955

Tracing are accomplished in a manner foreign to the writing processes. Consequently, the identifying data which exist in writings and by which they are identified are not present in tracings. Page 19

The forger traces, usually with considerable pressure, over the genuine signature, using a pencil, pen, stylus, or similar instrument and creates an indented signature outline on the document being forged. This indentation or depression outline is thereafter overwritten, using pencil or pen or ink. This sort of traced forgery likewise is usually readily apprehended because of its slow unnatural execution, the presence of indentations and depressions, and a lack of precise coincidence between the indented signature outline and its overwritten counterpart. Page 20

They [tracings] wear the chains of slow, unnatural, drawing movement, artificial studied attention to overall form of the letters, carbon traces, indentations and depressions, pencil traces, mixture of carbon outline and pencil or ink overwriting, "improving and correcting" strokes, faulty adherence to the line of writing caused by movement of the paper. Page 21

A precise agreement in the form of two

signatures establishes that one is a tracing of the other. Page. 21

James V.P. Conway, *Evidential Documents*, 2nd Edition, Charles C. Thomas Publishers, Springfield IL, 1972

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It is impossible for a person to write two identical signatures. Most tracings show *too many* identical characteristics to be normal. Tremor in the line quality, pressure, shading, and blunt endings and beginnings are indicators of traced forgeries. The only positive proof that a writing is a tracing rather than a simulation is the detection of guidelines or the actual model from which the tracing was made. Pages 306-307

Bradford and Bradford, *Introduction to Handwriting Examination and Identification*, Nelson-Hall Publishers, Chicago IL, 1992

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Traced signatures usually depart from genuine signatures (1) in fluency that is the result of greater speed of execution in normal, natural writings, (2) in line quality that a tracing lacks, (3) the presence of pen lifts and/or retouching that is indicative of the uncertainty of the writing instrument movement, and (4) the attendance of guidelines in the form of graphite or carbon lines or indentations. Page 292

Roy A. Huber and A.M. Hedrick, *Handwriting Identification: Facts and Fundamentals*, CRC Press, Boca Raton FL, 1999

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The typical traced forgery is drawn with a slow, measured stroke, which is usually filled with points of hesitation, uncertain movement, and sudden abrupt turns or jogs. This class of forgery typically contains a uniformly heavy stroke that lacks natural shading or pen emphasis common to natural writing. It is not unusual for the signature to display patchings and retouchings made in an effort to correct faulty letter forms. Retouching may even be made with the pen moving in the direction opposite to natural writing. In addition to pen lifts or breaks followed by careful splicing, there may also be indications of the pen stopping in the course of a stroke but remaining on contact with the paper and then without a lift continuing on. Page 187

Ordway Hilton, *Scientific Examination of Questioned Documents*, Elsevier Science Publishers, 1982

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The frequent comparing of the work with the model causes interruption of movement, inappropriate angles, pen lifts and pen rests in unusual places. Traced writings are rarely exact replicas of the models. In the tracing process, the hand does not reproduce precisely; it deviates slightly from the intended direction but quickly returns to the model line being followed. The undue attention a writer pays to imitating or tracing adds stress to the act, which inhibits free motion and causes inferior line quality. Among the characteristic features of tracings are fine tremor, pen lifts and pen stops in unusual places, careful patching, constant pressure, abrupt starts and endings, and inappropriate angles. Page 152

Unless a model is found, the writing cannot be proven to be a tracing. Page 153

Tracings rarely perfectly match the model but

are peculiar in the slight deviations in line direction that are regularly corrected by returning to the lines of the model. Page 155

Edna W. Robertson, *Fundamentals of Document Examination,* Nelson-Hall Publishers, Chicago IL, 1991

If a signature is geometrically identical with another, it points almost inevitably to a tracing; for neither the forger nor the owner of the signature himself can produce such a perfect copy. Page 42

Hanna F. Sulner, *Disputed Documents,* Oceana Publications, New York NY, 1966

In tracing the main object of the forger is to reproduce the exact designs of the letters, the size and angles of the letters, the spacing between the letters, the slop of the letters, the relative positions of the letters and the alignment of the letters signature. In short, in tracing an attempt is made to reproduce faithfully all the outward features of a genuine model signature. It, therefore, follows that if the questioned signature is found to be an exact replica or reproduction of the model, it is a strong indication, if not a conclusive proof that such a signature is a traced forgery. Page 235

M.K. Mehta, *Identification of Handwriting & Cross Examination of Experts,* 4th Edition, M.K. Mehta, Fred B. Rothman & So., S. Hackensack NJ,

Disclaimer: This list is not intended or claimed to be a total and all-encompassing listing of all references to tracing by the referenced authorities, but is presented for your convenience and possible use and/or research in the field of document examination.

Forensically Speaking - Identification of Printers

Compiled by Barbara Downer, CDE

Part One
Until recently it would have been impossible to tell which laser printer printed a certain document. But now researchers at Purdue University have developed a method that will enable authorities to trace documents to specific printers. Law enforcement agencies could use this technique to determine the exact printer from which a threatening note or counterfeit document was printed.

The process is two-fold. First, documents will be analyzed to identify unique characteristics for each printer. Second, printers will be designed to purposely embed individualized characteristics in documents. While the current focus is on laser printers, this process will later be expanded to inkjet printers.

Funded by the National Science Foundation, the findings were presented on Nov. 5, 2004 at the International Conference on Digital Printing Technologies in Salt Lake City. The author of the papers are Edward J. Delp, a professor of electrical and computer engineering at Purdue; Jan Allebach, also a professor of electrical and computer engineering; George Chiu, a professor of mechanical engineering; and engineer doctoral students Pei-Ju Chiang, Gazi N. Ali and Aravind K Mikkilineni.

A method counterfeiters use is to digitally scan currency and then use color laser and inkjet printers to produce fake bills. This method is also used by forgers to produce counterfeit passports and other documents.

"Investigators want to be able to determine that a fake bill or document was created on a certain brand and model of printer," Delp said. According to researchers, in testing 12 printer models, they have successfully identified documents printed with 11 out of the 12.

Delp believes they will eventually be able to identify not only the model, but also the specific printer that was used. This would enable investigators to determine authenticity of documents, such as airline boarding passes and passports.

The technique involves the use of specialized software to detect slight variations or printed characters, revealing subtle differences from one printer to another. So even if printers are the same model, they will have slight flaws and variations in their mechanical systems. It is these slight variations that result in subtly different characters.

One of the researchers believes that this will be possible because, for a company to make printers all behave exactly the same way would require an adjustment of the manufacturing tolerances to the point that the printer would be far too expensive to purchase.

The researchers are relying on a phenomenon called "banding" - the horizontal imperfections in the print quality of documents by those mechanisms that use rotating components. The problem is that components don't necessarily rotate at an exactly constant speed. The laser printer's cartridge has a photoconductor drum inside which rotates a laser beam scan back and forth along the drum. The drum is charged with

a coated material that releases its charge when exposed to light, turning on and off rapidly and selectively removing the charge in certain areas. Printing occurs when the toner is attracted to those areas that no long have a charge, forming letters or graphics that are transferred to sheets of paper.

One researchers calls this process "development." Since the drum is not rotating at a constant speed, if the drum slows down a bit, you get excessive development, so the print will look a little dark. And of course, the opposite happens when you get too little development, leaving the print a little light.

These minor imperfections of light and dark cause the imperfections in a text document or an image. And, because every printer has its own unique pattern of banding, the imperfections can be used to trace a document to a specific printer.

One problem is that if the printer cartridge is changed after a document is printed, the document no longer can be traced to that printer. Purdue researchers are overcoming this problem by creating software that embeds its own unique "extrinsic signature" in a printed document, regardless of which printer cartridge is in a machine. These artificially embedded "signatures" are too fine to be seen by the unaided eye, but can be detected with image-analysis techniques.

Part Two

In another development, some printer companies have developed a method to embed a code into a printed document. Small, scattered yellow dots are embedded when the document is about 20 billionths of a second from printing.

Several printer companies are encoding the serial number and the manufacturing code of their high-end color laser printers on documents those machines produce. The United States government, among others, is using the hidden markings to track counterfeiters. The printers put the serial number of each machine coded in little yellow dots in every printout. Within the printed words and margins, the millimeter-sized dot patterns appear about every inch on a page.

Since the dots are of minuscule size and are printed as yellow dots on white paper, they are virtually invisible to the naked eye. It is with a blue LED light, from even a keychain flashlight, and a magnifier, that the dots may be visible.

A counterfeiting specialist with the U.S. Secret Service stresses that the Government only uses the embedded serial numbers when alerted to a forgery or other criminal activity. This cooperation of the printer manufacturers with the government is already proving to be extraordinarily helpful to law enforcement.

References:

Purdue University News – October 2004
PCWorld.com – November 2004

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